NATURE Unhooked

MDC DISCOVER nature SCHOOLS

Student Book

On the cover: An American white pelican nets an Asian carp for a snack. Photo by Danny Brown.

Did you know?

Though they do not nest in Missouri, American white pelicans can be spotted during spring and fall migration. Pelicans help control fish populations and often hunt in groups cooperatively in shallow water.

Acknowledgments

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The Missouri Department of Conservation and the Missouri Department of Natural Resources have teamed up to bring you an all-new middle school science unit: Discover Nature Schools — *Nature Unhooked*.

The mission of the Conservation Department is to protect and manage the fish, forest, and wildlife resources of the state; and to facilitate and provide opportunities for all citizens to use, enjoy, and learn about these resources.

The mission of the Department of Natural Resources is to protect our air, land, and water; to preserve our unique natural and historic places; and to provide recreational and learning opportunities for everyone.

Together, our organizations cover the breadth of conservation and natural resource issues in the state. As part of our missions, we want to encourage students to be knowledgeable about our natural world and how we as humans are interdependent with and connected to nature.

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NATURE Unhooked

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1 the STRUCTURE and PROPERTIES of Water

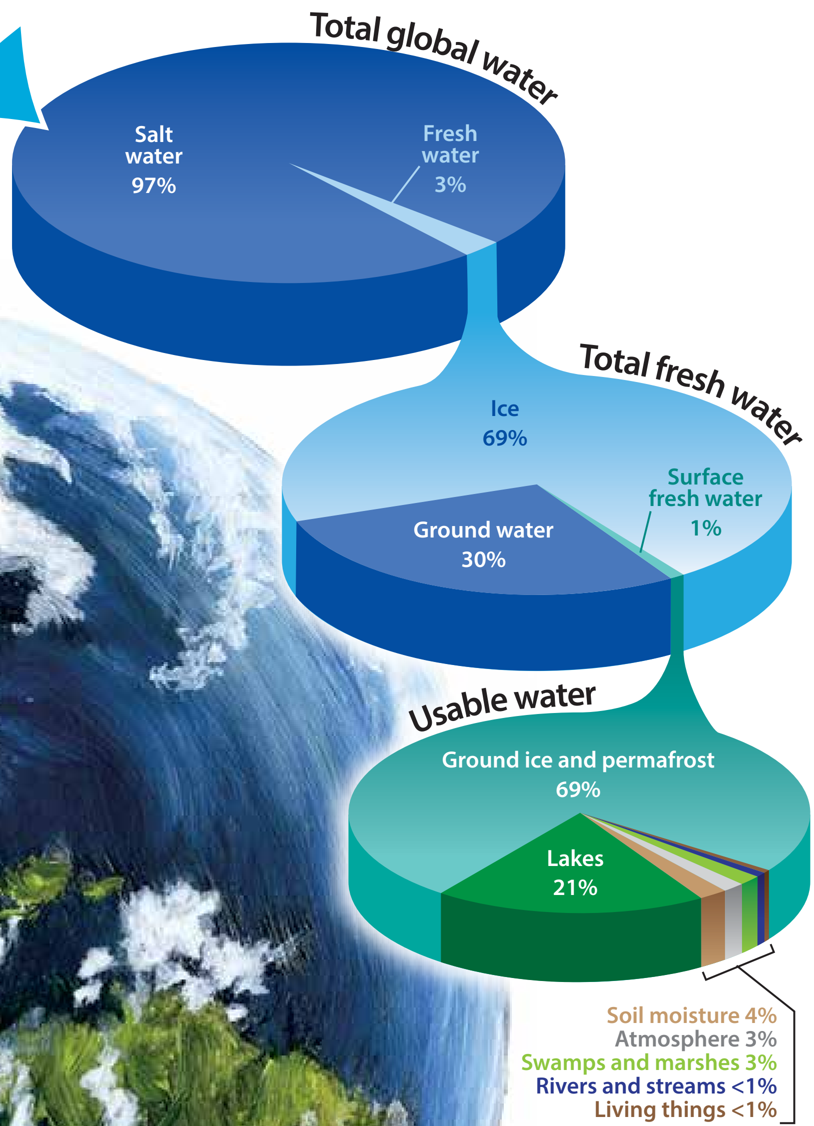
BIG IDEAS

- ➤ Water is a simple molecule.
- ➤ Water's structure gives it distinct properties.
- ➤ Water's properties are important for life.

Earth is called the Blue Planet. There are many other blue planets hurtling around the universe, but none are blue for the same reason as Earth. The planet we call home is painted blue by the water of its oceans, rivers, clouds, and ice. In fact, water covers more than 70 percent of Earth's surface. And it's this water — one of the universe's simplest substances — that makes life possible on our careening ball of rock. In this chapter we'll learn how a water molecule's simple structure gives it unique properties that are necessary for life.

Water, water everywhere? It depends.

Earth contains 1,355,000,000,000,000,000,000 liters of water. Although that sounds like a lot, only a small percentage is available to living things.



Did you know? Scientists have found evidence that 30 to 50 percent of the water on our planet is older than the Earth itself.

Did you know? Water molecules are really small! Each is only about 0.0000003 of a millimeter wide. It would take more than 60 million water molecules lined up side-by-side to stretch across a penny.

Water is a simple molecule.

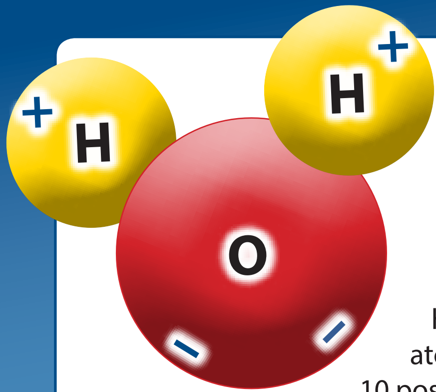
All matter — both living and nonliving — is made of **atoms**. Atoms bond with other atoms to form **molecules**. Some molecules are made of just two atoms. Other molecules are made of thousands of atoms. Water is made of three atoms: two hydrogen atoms and one oxygen atom (H_2O). The atoms are held together by strong bonds that are hard to break.

Like all molecules, water is a pure substance with distinct properties. One of its properties is its shape. Water's atoms are arranged in such a way that they look like a teddy bear's head. The angle between the hydrogen atoms (teddy bear's ears) and the oxygen atom (teddy bear's head) is always in this configuration. Every molecule of water — in the streams and oceans of the world, in raindrops and dewdrops, in our bloodstream and in the fog of air we exhale on a cold day — looks like this.

One molecule of water (just those three atoms) is the smallest unit of water you can obtain. If you break the molecule apart, it stops being water and instead becomes hydrogen and oxygen — two substances with properties that are quite different from those of water.

Did you know?

Water is the most abundant ingredient in living things, usually making up 60 to 75 percent of an organism's weight. The average 12-year-old has nearly 70 pounds of water sloshing inside his or her body.



Water's structure gives it distinct properties.

Atoms are composed of smaller particles. **Protons** have a positive charge (+). **Electrons** have a negative charge (–). Protons stay in the nucleus at the center of the atom. Electrons zip around the nucleus like swarms of bees. Water's two hydrogen atoms each contain one proton and one electron. Water's oxygen atom has eight protons and eight electrons. Thus, a water molecule contains 10 positively charged protons and 10 negatively charged electrons.

In some molecules, the protons and electrons are evenly distributed throughout the molecule. But water is different. Because oxygen has eight protons, it has a greater ability to pull electrons away from the hydrogen atoms. (Remember, opposite charges attract.) So, the electrons in a water molecule tend to swarm around the oxygen atom more often than the hydrogen atoms. Because electrons are negative, the oxygen end of a water molecule (teddy bear's chin) has a slight negative charge, and the hydrogen ends (teddy bear's ears) have a slight positive charge. A molecule such as water, in which the charges aren't evenly distributed, is called a **polar molecule**. (Think of a battery or a magnet that has positive and negative poles.) It's this polarity that gives water many of its distinct properties.

Water's properties are important for life.

COHESION

Opposites attract — it's an undeniable fact of physics and cheesy romance novels — and water is no different. The positively charged hydrogen ends of a water molecule are attracted to negatively charged oxygen ends on nearby water molecules. This causes water molecules to stick to each other. Chemists call the points where they stick together **hydrogen bonds**.

The attraction of one molecule to another molecule of the same kind is called **cohesion**. Cohesion explains why raindrops are round and why water beads up on a freshly waxed car. Cohesion produces surface tension, which explains why water striders can skim across a pond's surface without sinking and why doing a belly flop off the high dive hurts so much. More importantly, cohesion (along with adhesion, which we'll learn about next) plays an important role in moving water and other substances throughout the bodies of living things.

Cohesion allows water to form a dome over this penny.

ADHESION

Adhesion is the attraction between two different kinds of molecules. If you've ever noticed dewdrops clinging to a leaf, you've seen adhesion in action. Adhesion is also responsible for the slight curve you see when you pour water into a graduated cylinder. The water is attracted to the glass at the sides of the cylinder and curves downward at the center. (Because of adhesion, you should always read the volume measurement at the bottom of the curve.)

Missouri's tallest oak tree stretches 150 feet into the sky. Plants as tall as this need good plumbing. How else could they get water from their roots to the top of their branches? A plant's plumbing is composed of a series of dead cells that form tiny tubes. Adhesion draws water up into these tiny tubes. As the water molecules move upward, they tug — because of cohesion — at the molecules they're attached to. In this way, water is pulled up through the tubes from the roots to the leaves.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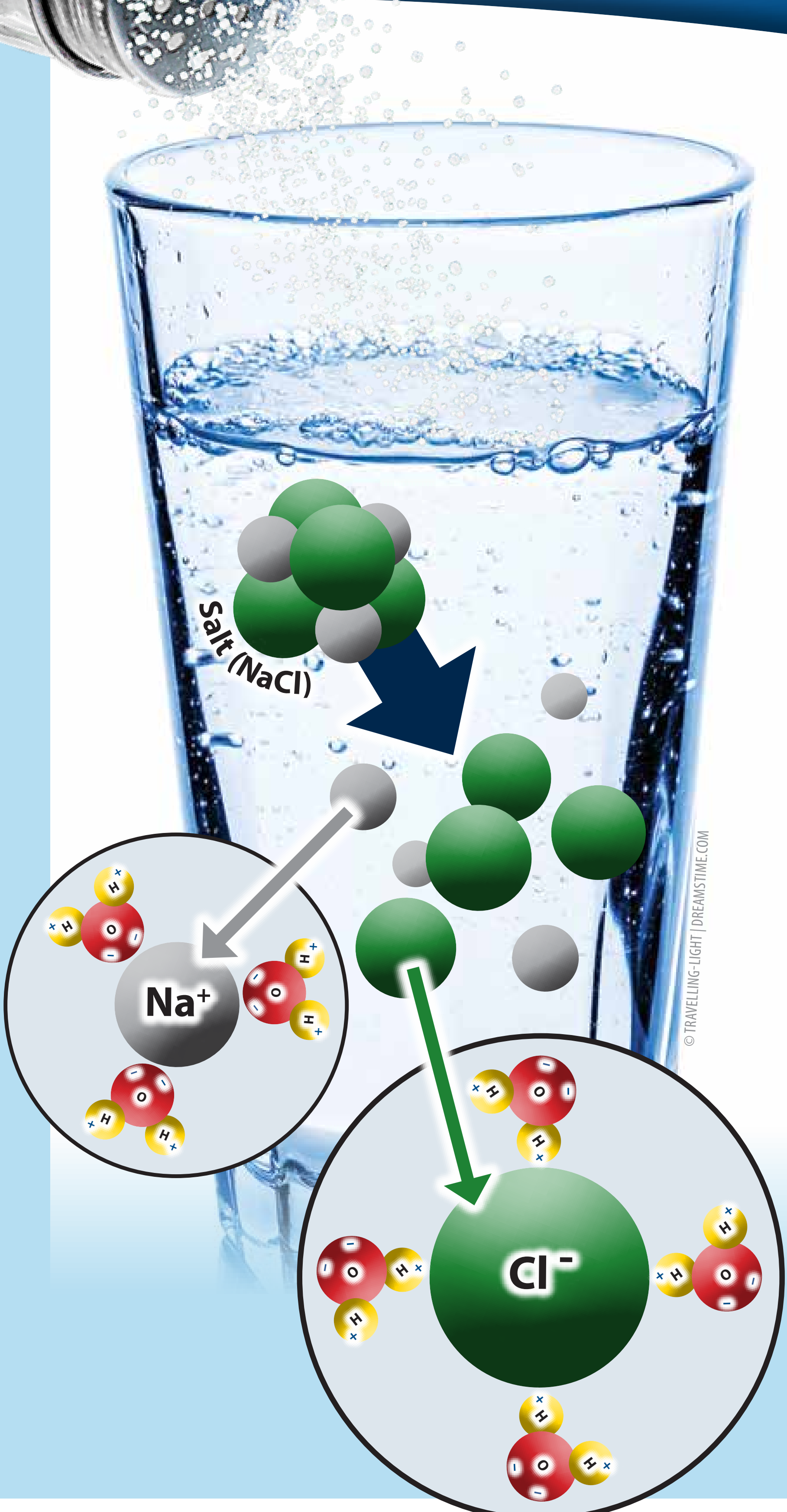
THE UNIVERSAL SOLVENT

Because water is a polar molecule, it is able to attract and pull apart other polar molecules. For example, when table salt, which is made of sodium and chlorine atoms, is mixed into water, the negative ends of the water molecules are attracted to the positively charged sodium atoms, and the positive ends of the water molecules are attracted to the negatively charged chlorine atoms. This causes the sodium and chlorine atoms to separate and dissolve in water.

When a substance dissolves in another substance it forms a **solution**. The **solute** is the substance that dissolves. The **solvent** is the substance that does the dissolving. Many substances dissolve in water. That's why water is called the universal solvent.

Water's knack for dissolving things makes it an excellent vehicle for moving molecules into, out of, and inside living things. Many of life's most important molecules — including sugars, amino acids, and proteins — dissolve in water. Water transports these molecules into and out of cells. On a larger scale, the blood pulsing through your veins and arteries is about 92 percent water. This water helps transport oxygen and nutrients to cells and also helps carry away wastes, such as carbon dioxide. Sweat and urine, both of which are mostly water, play roles in removing wastes from our bodies.



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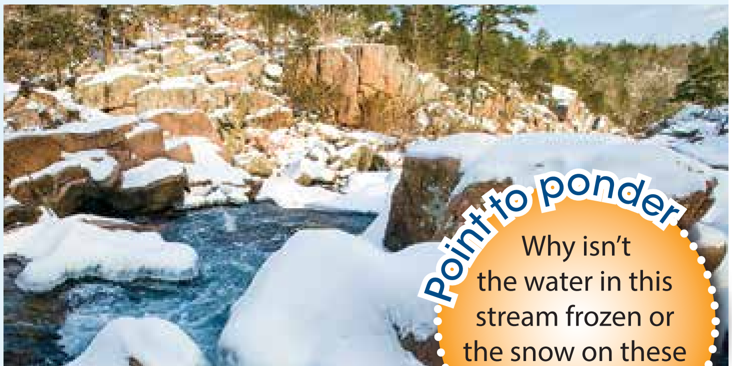
Did you know?

Most substances shrink as they get colder. Water is weird. It expands when it freezes. That's why soda cans explode when you leave them in the freezer.

HIGH HEAT CAPACITY



Point to ponder

Why isn't the water in this stream frozen or the snow on these rocks melted?

Molecules are constantly in motion, as jittery as your little brother after eating Halloween candy all night. Even the molecules in your desk are jiggling in place. **Temperature** is a measure of how much the molecules are moving. The more wildly a substance's molecules are moving, the higher its temperature.

Like hip hop music at a dance party, energy causes molecules to move more. Heat is a form of energy. As heat is added to a substance, its molecules move more rapidly and spread out to occupy more space. This is why substances usually expand when heated and shrink when cooled.

But water's molecules don't want to let go of each other. The hydrogen bonds that connect one water molecule to another are strong. It takes a lot of energy to break these bonds apart so that water's molecules can start dancing. Because of these bonds, water can absorb a lot of heat before its temperature increases. In other words, water has a high **heat capacity**.

Water's high heat capacity makes it vital to living things. Many of the chemical reactions that occur inside cells happen in only a narrow range of temperatures. Water, because of its high heat capacity, moderates temperatures inside organisms so that the reactions can proceed. On a much larger scale, water in the oceans and in the atmosphere helps moderate Earth's temperatures so that life can exist.

DENSITY

Water can exist in three states: solid, liquid, and gas. In a **gas**, molecules are spread widely apart and moving wildly about. The molecules come into contact with each other only when two molecules happen to collide in their wanderings. In a **liquid**, molecules are constantly in contact with each other but still move about freely. In a **solid**, molecules are packed tightly together and, though they may jiggle in place, don't move about freely.

Density is a measurement of how much matter is packed into a specific space. To find an object's density, you divide its mass by its volume ($D = M/V$). It makes sense, then, that lots of molecules packed into a small space have a higher density than a few molecules packed into a large space. So in most substances, solids are more dense than liquids.

Water is weird. When water freezes, the hydrogen bonds joining the molecules lengthen. This pushes the molecules farther apart and makes solid water less dense than liquid water. This is important for aquatic organisms. When a lake freezes, the ice forms first on the surface (not from the bottom up). This creates an insulating layer over the liquid water below, which provides living space for aquatic organisms until the ice melts.

Bald eagle

KEEP Discovering

The substances that are dissolved in water influence what lives there. For an illustration of this, grab a dip net, a pair of tweezers, and an ice cube tray and head to your local stream. There, find a riffle and a pool. Riffles are shallow, fast-moving stretches where water splashes over rocks. Pools are calmer, deeper stretches.

Use the dip net to strain up aquatic invertebrates (animals without a backbone) that live in the riffle. (You may need to drag the net through the gravel at the bottom.) Use forceps to gently pluck the invertebrates out of the net and place them in one end of an ice cube tray filled with water. Fill the other end of the tray with invertebrates captured from a pool.

Now take a close look at the critters in each end of the tray. Do they look alike?

The answer has something to do with water's role as a universal solvent. Oxygen dissolves in water. When water splashes over the rocks in a riffle, water molecules grab oxygen molecules from the air and hang on to them. Because of this, water in a riffle contains more dissolved oxygen than water in a pool. And, the organisms that live in a riffle need more oxygen than those that live in a pool.

MAKE THE Connection

On Christmas Eve 1988, a 2-foot-wide steel pipeline burst near Vienna, Missouri, spewing more than 860,000 gallons of crude oil into the Gasconade River. Within 24 hours, a slick of oil 15 miles long and more than a foot thick in places had turned the Gasconade's clear green water deathly black. As crews struggled to contain the spill, the Gasconade carried the oil into the Missouri River, where traces reached St. Louis within the week. The spill became the worst inland oil disaster in U.S. history, and it cost the Shell Oil Company $22 million in fines, environmental cleanup, and court costs.

Oil, being a nonpolar substance, does not dissolve in water. Given what you know about how water's polarity makes it a good solvent, do you think it is easier to clean up polar substances or nonpolar substances? Explain your answer.

PHOTO BY GARY BOHN, COURTESY OF THE ST. LOUIS POST-DISPATCH

2 THE INCREDIBLE Journey

BIG IDEAS

➤ Water moves continuously among the oceans, the atmosphere, the land, and living things.
➤ Sunlight and gravity drive the water cycle.
➤ Water changes state as it moves through the water cycle.
➤ Watersheds connect Earth's ecosystems.
➤ Water shapes the Earth through erosion and weathering.

When Earth formed, it was a ball of hot, molten rock that contained not a single drop of water. Scientists aren't completely sure where our water came from, but evidence suggests icy asteroids crashed into Earth and turned our home hunk of rock from red-hot to watery blue.

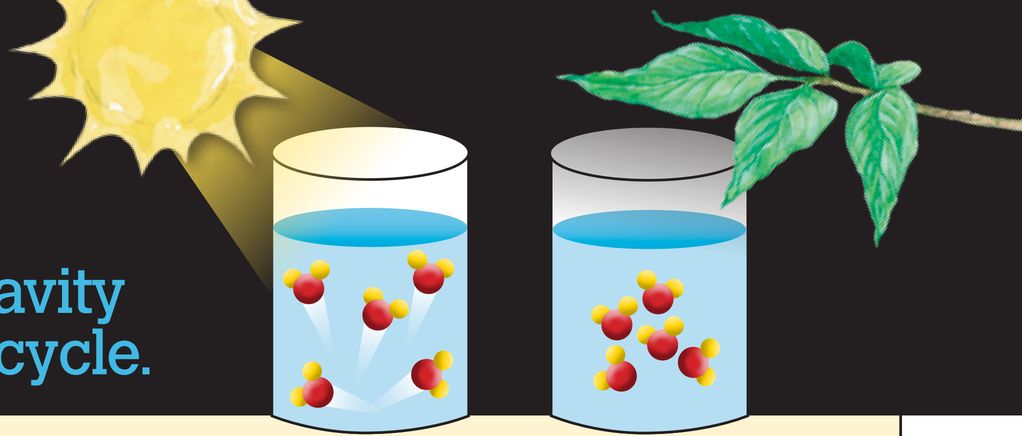
Since then, the amount of water on Earth has essentially stayed the same. The water you used to brush your teeth may have dribbled from a duck-billed dinosaur's mouth. The water you sipped before class may have been locked in a glacier thousands of years ago. Your blood may contain water that once flowed through a fish hundreds of years ago. In short, the water you use today may have rained from the sky two weeks ago, but the molecules themselves have existed for much longer.

Water moves continuously among the oceans, the atmosphere, the land, and living things.

Water is found nearly everywhere on Earth, but individual water molecules rarely stay put for long. Imagine that you are a water molecule. Over time, you might bob above a coral reef in the Caribbean, sail through the sky over Paris, fall softly in a snowflake atop Mount Everest, roar through the Grand Canyon, splash down upon an Ozark forest, and rise from the roots to the highest leaf of an oak tree.

What you just imagined is part of the **water cycle**, the movement of water molecules among Earth's oceans, atmosphere, land, and living things. Water molecules move through the cycle, over and over. The water cycle plays an important role in weather and climate by moving water throughout the atmosphere. It shapes Earth's landscapes by carving out canyons, valleys, river channels, and floodplains. The water

Sunlight and gravity drive the water cycle.



When water — or any substance — gains energy, its molecules move faster and spread farther apart.

Sunlight streaks across 150 million kilometers of cold, empty space to heat water on Earth's surface. This causes water to rise into the atmosphere. Why? Because heat is a form of energy. When water — or any substance — gains energy, its molecules move faster and spread farther apart. As water's molecules spread out, water becomes less dense, which causes it to rise above substances that are more dense. (Density, remember, is a measure of how much matter is packed into a given space.)

If sunlight is responsible for moving water generally upward in the water cycle, then gravity is responsible for moving water generally downward. Matter is attracted to other matter. The force of attraction is called **gravity**. Water — whether it's a solid, liquid, or gas — has mass, so it's pulled toward the center of the planet by Earth's gravity. Gravity causes snow to fall from the sky, glaciers to creep down a mountain, rain to seep into soil, and rivers to flow downhill into a lake or an ocean.

Did you know?

The sunlight you're seeing right now was produced by the sun a few minutes ago. Even though it moves at a speed of 300,000 kilometers per second, it still takes light 8 minutes to make the trip to Earth.

Fish harvest

Osage Indians

Rain clouds

Canada geese

cycle cleans and purifies water, and it distributes water among Earth's ecosystems so it can be used by living things.

What powers water's incredible journey? Two things: energy from the sun and the pull of Earth's gravity.

Point to ponder

How long does it take for a water molecule to make a full trip through the water cycle?

the WATER CYCLE

Water changes state and location as it moves through the water cycle.

Water is the only substance on Earth that exists naturally in three states: solid, liquid, and gas. For each of the processes below, pay attention to the changes of state that occur and the roles played by sunlight, gravity, wind movements, and the Earth's heat.

Heads up!

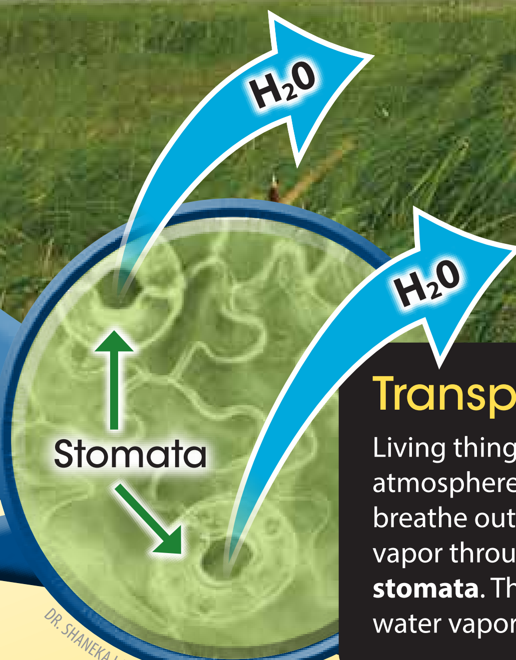
Water molecules don't follow the same path through the water cycle every time. They may skip some of these processes on one leg of their journey and skip others when they make a new trip through the cycle.

Did you know?

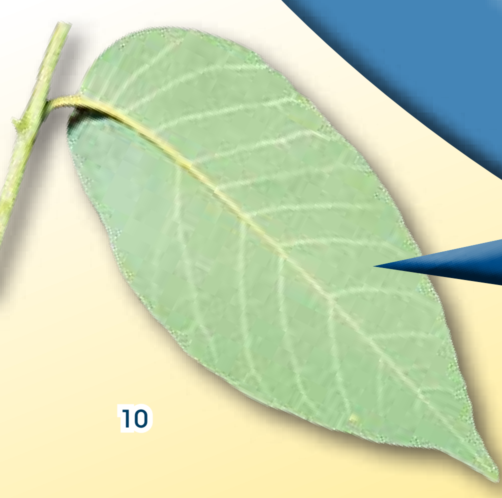
Once it evaporates, a water molecule spends, on average, about 10 days in the atmosphere.

Evaporation

Sunlight warms water on Earth's surface and changes the water into invisible water vapor. This change of state — from liquid to a gas — is called **evaporation**. When water evaporates, it leaves behind substances that were dissolved in it, such as salts and pollutants. Winds move water vapor all around the Earth.



DR. SHANEKA LAWSON, USDA FOREST SERVICE



Did you know?

Through transpiration, a large oak tree can release about 150,000 liters of water a year.

Transpiration

Living things can also move water into the atmosphere. Every time you exhale, you breathe out water vapor. Plants release water vapor through tiny holes in their leaves called **stomata**. The process in which plants release water vapor is called **transpiration**.

Runoff

When precipitation hits the ground faster than it can soak in, it flows downhill and becomes **runoff**. Melting snow or ice becomes runoff, too. Runoff moves quickly down steep slopes, and little soaks in. Hard surfaces, such as rock or pavement, also reduce the amount that soaks in. These **impermeable surfaces**, such as rock or pavement, do not allow runoff to be absorbed. The faster water flows, the more power it has to pick up and carry substances such as soil.

Three-toed box turtle

Infiltration

Some precipitation that falls onto land soaks into the ground. This process is called **infiltration**. The soaked-in water may remain near the surface as soil moisture, evaporate back into the atmosphere, be taken up by plant roots, or trickle slowly downward to fill porous rock layers (full of tiny holes) called **aquifers**.

Precipitation

When water molecules condense on microscopic particles such as dust specks, the molecules group together and gain enough mass to be pulled down by gravity. The result is **precipitation**. Precipitation can be liquid (rain) or solid (hail or snow).

Bison

Crystallization

When water becomes colder — that is, when it loses heat energy — its molecules slow down and it becomes less dense. If enough energy is lost, water changes from liquid to solid — it freezes. This process is called **crystallization**, and it results in ice, snow, sleet, and hail.

Condensation

As water vapor rises in the atmosphere, it cools and changes back into liquid, forming clouds or fog. (Contrary to popular belief, clouds are not made of water vapor. They're made of liquid water.) This change of state — from gas to liquid — is called **condensation**. Water vapor also condenses on ground-level surfaces, forming **dew** or **frost**.

WATERSHEDS

Watersheds connect Earth's ecosystems.

Runoff flows downhill in tiny trickles. Trickles combine to carve ditches, streams, and rivers. These water channels and the land that drains into them are called **watersheds**.

Watersheds are separated from each other by mountains, hills, and ridges. If you were to stand atop a hill that separates one watershed from another, you could pour one glass of water down one side of the hill and another glass down the other side, and the water would eventually end up in different streams.

Everything that happens on the land in a watershed affects the water moving through the watershed. As runoff flows downhill, it picks up whatever is on the ground — soil, fertilizer, oil, animal wastes — and carries it into streams, rivers, wetlands, lakes, and oceans. Pollution that comes from a single source, such as the discharge pipe from a factory, is called **point-source pollution**. Pollution that comes from many sources — such as pesticides, herbicides, and fertilizers that are picked up by runoff from yards, parking lots, streets, golf courses, and farm fields — is called **nonpoint-source pollution**.

We All Live in a Watershed

Scientists measure watersheds at different scales. Watersheds can be as small as your yard or as big as half a continent. Small watersheds combine to form big watersheds, big watersheds combine to form bigger watersheds, bigger watersheds combine to form ginormous — well, you get the picture. Missouri lies within the Mississippi River watershed. Although it is the largest watershed in the United States, it's made up of many smaller watersheds.

1 Small watersheds — like the one in your backyard — are drained by tiny trickles and ditches small enough to step across.

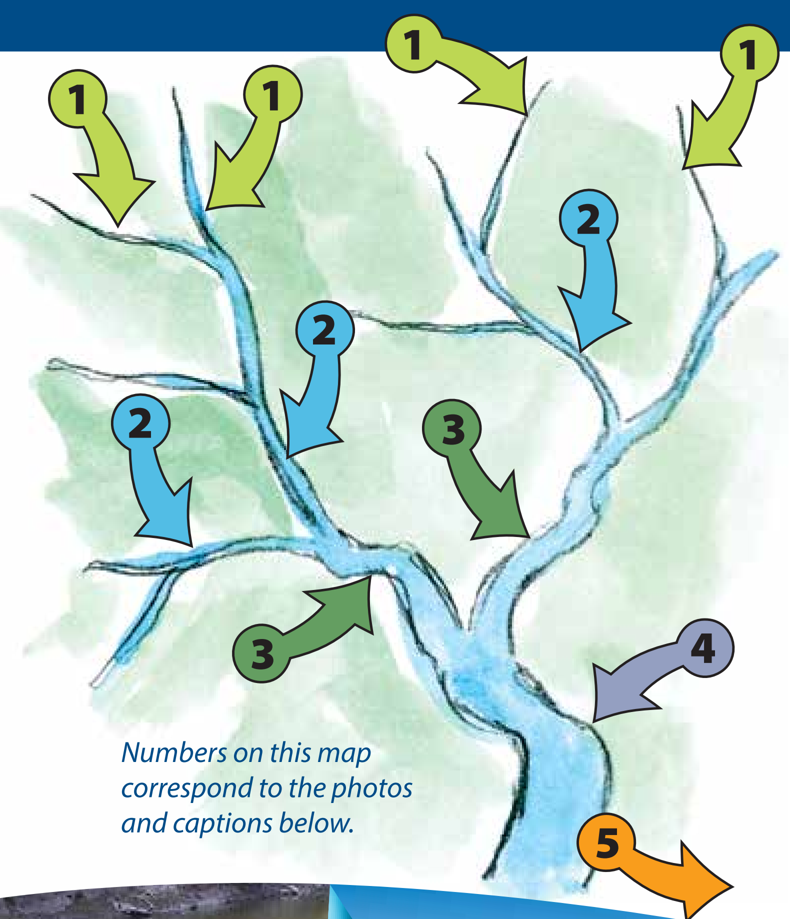
2 Trickles combine to form small streams such as Hinkson Creek, which flows through the city of Columbia. The land that drains into Hinkson Creek — the Hinkson Creek watershed — covers about 232 square kilometers.

3 Small streams combine to form medium-sized streams. A stream that flows into a larger body of water is called a **tributary**. Hinkson Creek is a tributary of Perche Creek. Perche Creek drains about 415 square kilometers of land.

KEEP Discovering

People who would never dream of polluting a stream may not think twice about pouring antifreeze, pesticides, paint, or motor oil down a storm drain. Every time it rains, runoff may wash street litter, yard debris, pet wastes, and other pollutants into storm drains. In most communities, storm drains flow directly into nearby streams, rivers, lakes, or sinkholes. Stenciling "Dump No Waste, Drains to Streams" near a storm drain is an easy way to remind people that just because pollution disappears down the drain, it isn't gone forever.

If you're interested in storm-drain stenciling, consider joining a Stream Team. Stream Teams are made up of young people and adults who love clean water, good fishing, and healthy habitats for plants and animals. Being part of a Stream Team is a fun, hands-on way to care for and protect your local waterways. To learn more about storm-drain stenciling and Stream Teams, float over to **mostreamteam.org**.



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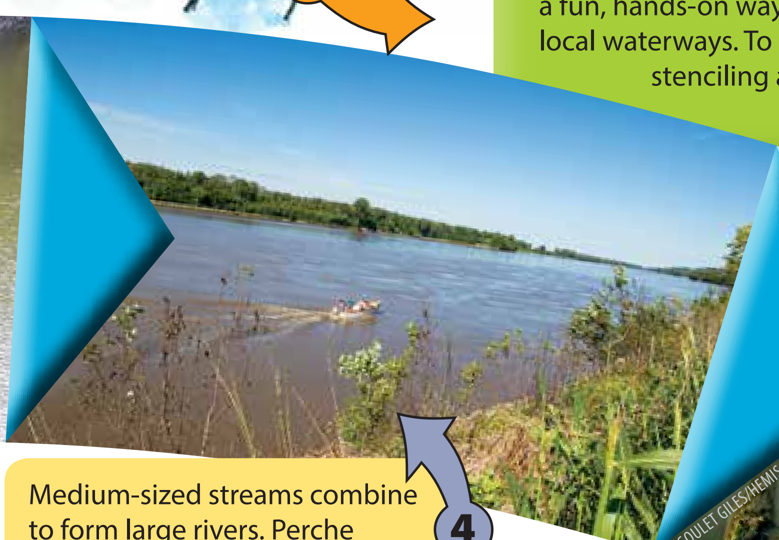
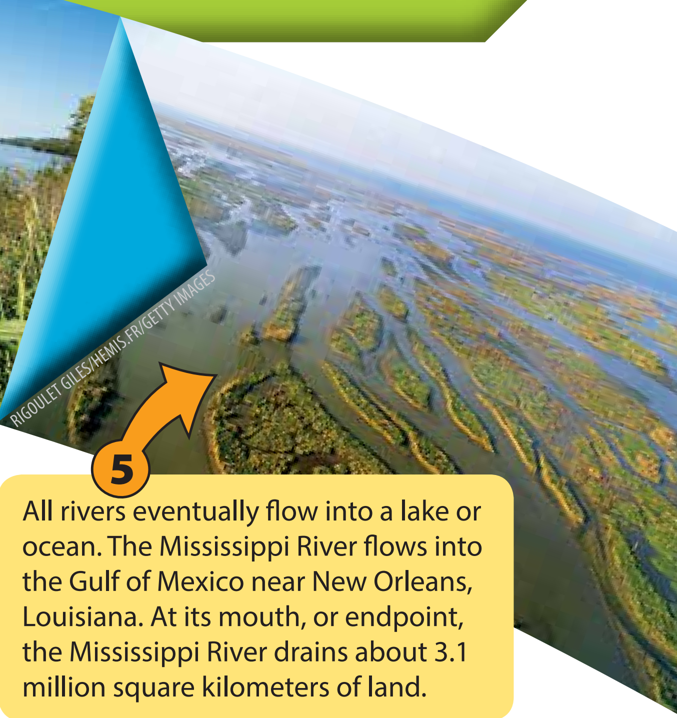




4

Medium-sized streams combine to form large rivers. Perche Creek flows into the Missouri River, which drains about 1.3 million square kilometers of land. The place where two streams or rivers meet is called a **confluence**. The confluence of the Missouri and Mississippi rivers is near St. Louis.

5

All rivers eventually flow into a lake or ocean. The Mississippi River flows into the Gulf of Mexico near New Orleans, Louisiana. At its mouth, or endpoint, the Mississippi River drains about 3.1 million square kilometers of land.

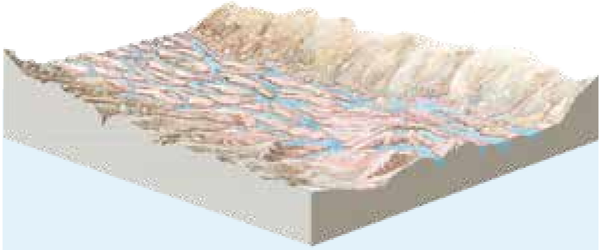
WEATHERING AND EROSION

Water shapes the Earth through weathering and erosion.

You'd have a tough time finding a better way to spend a steamy August afternoon than splashing around in Johnson's Shut-Ins State Park. Here, the clear waters of the East Fork of the Black River swirl around massive igneous boulders, rush through canyon-like gorges, and churn inside cool, deep potholes. Humans likely have been splashing in these pools and chutes for thousands of years. The Shut-Ins themselves, however, have been around much longer.

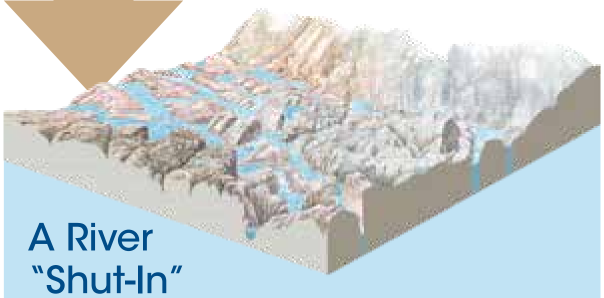
When the Ozarks were formed, volcanoes hurled hot gases and melted rock (magma) high into the air. The magma fell and cooled, forming mountains of igneous rock. Oceans rose over the igneous mountains, covering them with layers of sedimentary rock. Later, geologic forces pushed the Ozark region upward, the oceans dropped, and the East Fork of the Black River began flowing …

Johnson's Shut-Ins State Park



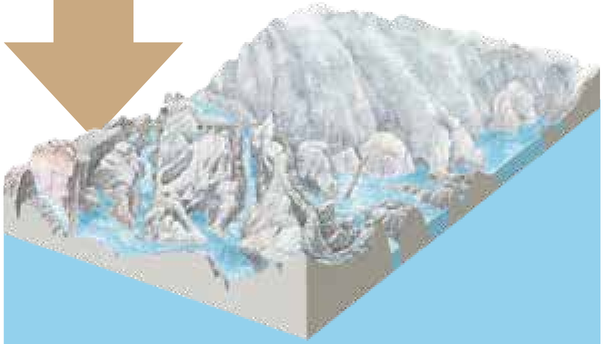
Weathering and Erosion of Sedimentary Rock

As the river flowed through a wide valley, the friction of its water, along with sand and gravel that the water carried, scoured away soft sedimentary rock.



A River "Shut-In"

Harder igneous rock did not wear away as quickly, and over time the river was "shut in" to form a narrow, rushing channel.



Today – Johnson's Shut-Ins

Small cracks formed in the igneous rocks. Over time, the rushing river made the cracks wider and deeper, forming the waterpark we now call Johnson's Shut-Ins.

The processes that formed Johnson's Shut-Ins are the same that shape the rest of the Earth. **Weathering** is the process by which solid rock is broken into smaller pieces. **Erosion** is the process that carries away the smaller pieces formed by weathering. Water, as you might have guessed, plays a role in both.

Did you know?

Raindrops fall at a speed of about 30 kph and can splash mud 60 cm high and 150 cm away.

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Weathering

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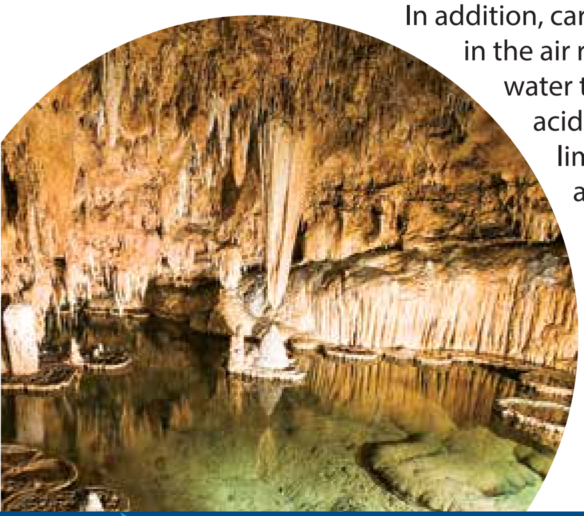
When water slips into a crack in a rock and then freezes, the ice acts like a wedge, pushing with great pressure against the sides of the crack. (Water, remember, expands when it freezes.) As the water melts and refreezes, the crack gets larger and larger until the rock eventually breaks.

Minerals that make up certain rocks dissolve in water, causing the rock to crumble into smaller pieces. In addition, carbon dioxide in the air reacts with water to form a weak acid that dissolves limestone. Caves and sinkholes throughout the Ozarks were formed by this type of weathering.



Erosion

Moving water packs a powerful punch. Raindrops strike Earth with a force of nearly 1 kg/cm^2. The impact creates tiny craters in the soil. It even wields enough force to break loose tiny fragments of solid rock.

Friction from water flowing downhill can scour away loose rock and soil. Rushing water in a flood-swollen river can carry sand, gravel, rocks, and even boulders, all of which slam into the river channel, hammering away still more rocks.

Turbidity is a measurement of how clear a liquid is. Erosion affects turbidity because the more sediments that are suspended in water, the cloudier (or more turbid) the water becomes. Phytoplankton (tiny plants growing in water) also affect turbidity.

MAKE THE Connection

People who care about clean water often say, "We all live downstream." What they mean is that we all live in a watershed, and what we do in the watershed affects not only our immediate surroundings but also the water, land, plants, wildlife, and people downstream.

Missouri contains many major watersheds. Which one do you live in? How many people also live there? How is the land used in your watershed? Is your watershed polluted, and if so, by what? For answers to these questions, visit **on.mo.gov/1UF2129**.

3 MATTER and Energy

BIG IDEAS

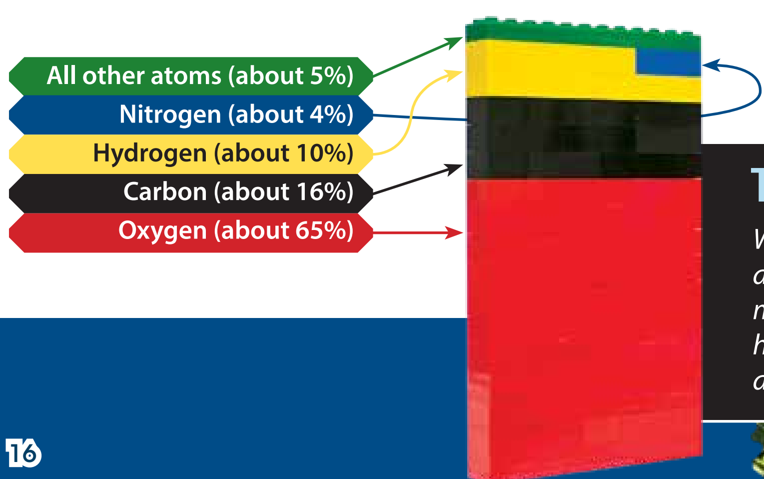
- ➤ Organisms are made of atoms.
- ➤ Organisms need energy to grow, survive, and reproduce.
- ➤ Producers get energy from the sun.
- ➤ Consumers get energy from other organisms.
- ➤ Food webs show how energy flows among organisms.
- ➤ Energy makes a one-way trip through ecosystems.
- ➤ Atoms are recycled over and over again.

At first glance, it seems as if this beaver and this oak tree have nothing in common. One is a chubby aquatic animal. The other is a towering, acorn-producing plant. But if you look closely — really, *really* closely — you'll find that they're both made of the same stuff and powered by the same energy.

Organisms are made of atoms.

Atoms are the building blocks of all matter, both living and nonliving. Atoms combine with other atoms to form molecules. Molecules form cells, tissues, organs, and organisms. Stack a whole bunch of atoms one way, and you get a beaver's whisker. Rearrange the same atoms another way, and you get the bark on an oak tree.

Organisms can't manufacture atoms. They get the atoms they need from the ecosystem in which they live. Some organisms, such as beavers and other animals, get atoms by eating, drinking, and breathing. Other organisms, such as plants and fungi, get atoms by absorbing them from their surroundings.



The Building Blocks of Life

We're all built with the same stuff. The mass of nearly any organism, from a bacterium to a beaver, is made up of just four kinds of atoms: oxygen, carbon, hydrogen, and nitrogen. About 75 other kinds of atoms are vital for life but occur in small quantities.

Organisms need energy to grow, survive, and reproduce.

Everything an organism does requires energy. The gnawing of a beaver's chompers, the growth of new cells in an oak tree's leaf, the flap of a bird's wings, the movement of your eyes as you read this sentence — they all require energy.

Energy cannot be created or destroyed. It can, however, change from one form into another. Light, heat, sound, electricity, chemical energy, and mechanical energy (movement) are all forms of energy. Organisms get the energy they need either by changing light from the sun into chemical energy or by consuming other plants and animals. They use the chemical energy to move, grow, survive, and reproduce. In the process, some of the chemical energy gets changed into heat and escapes into the atmosphere.

Did you know? Using nothing but its teeth, a beaver can gnaw down a 12-centimeter-wide willow tree in under three minutes.

Beaver

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PRODUCERS

get energy from the sun.

We all run on sunshine. The energy that sustains nearly every living thing comes from sunlight. Plants, algae, and some microorganisms can change light energy from the sun into chemical energy stored in sugar molecules. Biologists call these organisms **producers** because they take a form of energy that can't be used to power life (sunlight) and *produce* a form of energy (sugars) that can be used to power life. They accomplish this through the process of photosynthesis.

Inside an organism's cells, sugar molecules can be rearranged and combined with other molecules to form all the pieces and parts of a cell, and in turn, all the pieces and parts of an organism. This is how producers grow and reproduce: by turning sugars into new cells. Sugars can also be used to fuel all of the activities needed to maintain life.

Photosynthesis

Photosynthesis occurs in the cells of plants and other producers. During photosynthesis, energy from sunlight is used to power chemical reactions that change six molecules of carbon dioxide (CO_2) and six molecules of water (H_2O) into one molecule of sugar ($C_6H_{12}O_6$) and six molecules of oxygen (O_2). A chemist might simplify the process of photosynthesis with an equation that looks like this:

$$\mathbf{6CO_2 + 6H_2O\ (+\ sunlight) \rightarrow C_6H_{12}O_6 + 6O_2}$$

Notice that there are the same number of atoms on both sides of the arrow. Go ahead, count them. Like energy, atoms can't be created or destroyed. They can, however, be rearranged and recombined to form new molecules.

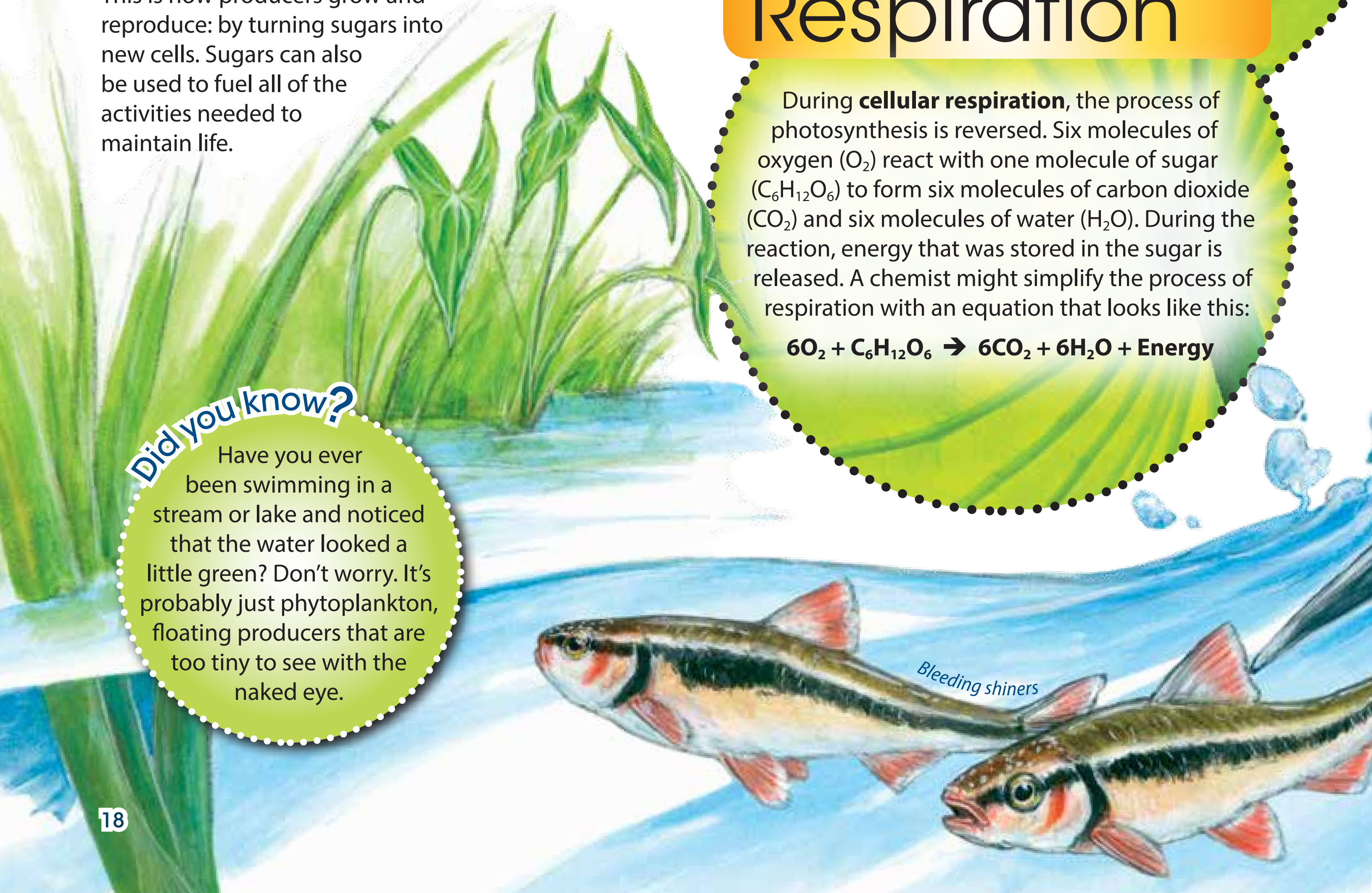
Respiration

During **cellular respiration**, the process of photosynthesis is reversed. Six molecules of oxygen (O_2) react with one molecule of sugar ($C_6H_{12}O_6$) to form six molecules of carbon dioxide (CO_2) and six molecules of water (H_2O). During the reaction, energy that was stored in the sugar is released. A chemist might simplify the process of respiration with an equation that looks like this:

$$\mathbf{6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + Energy}$$

Did you know?

Have you ever been swimming in a stream or lake and noticed that the water looked a little green? Don't worry. It's probably just phytoplankton, floating producers that are too tiny to see with the naked eye.



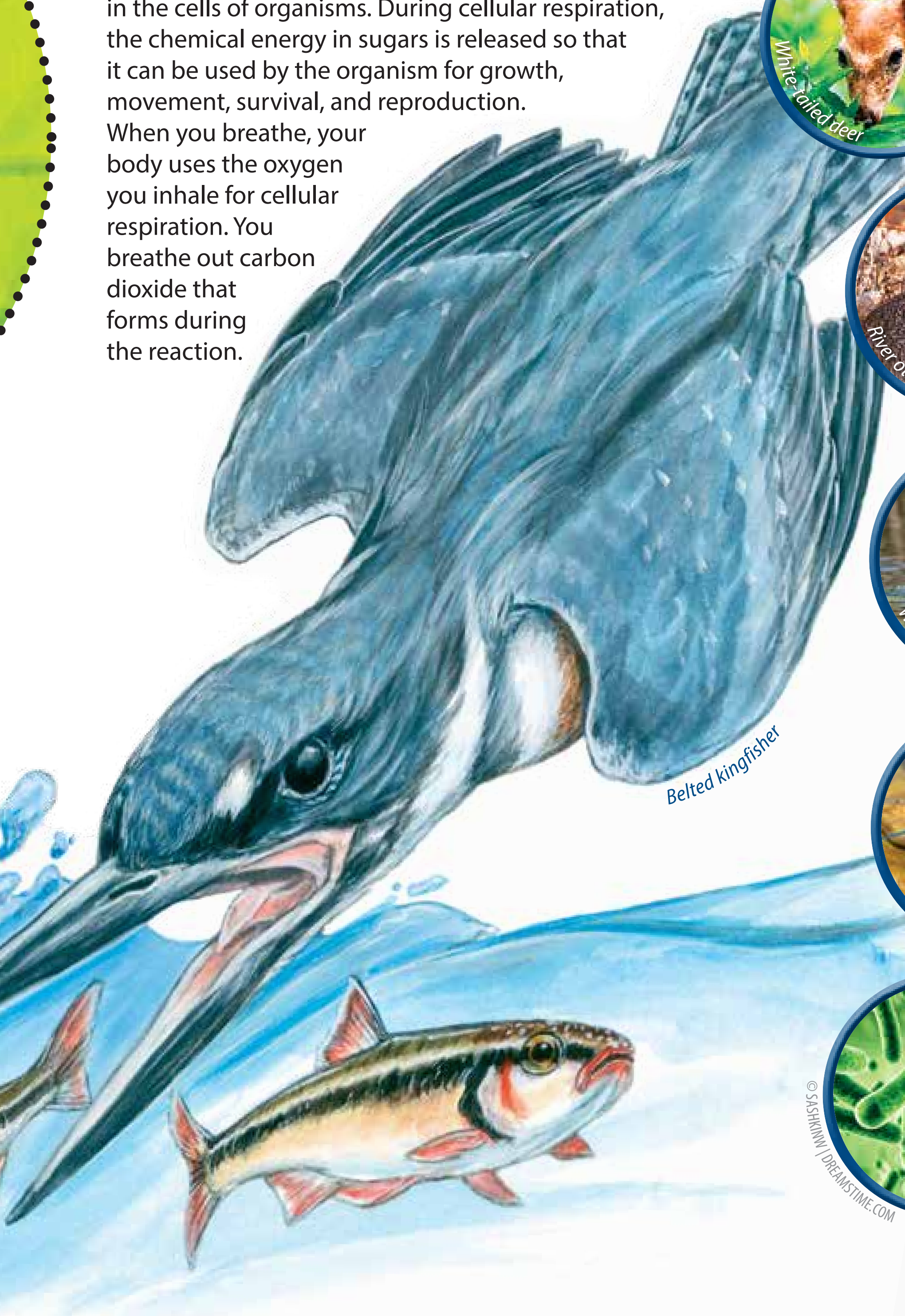
Bleeding shiners

CONSUMERS

get energy from other organisms.

Although only producers can change sunlight into chemical energy, nearly every organism — from plants to people — can use sugars for energy. When one organism eats another, the energy stored in the tissues of the "eaten" are passed on to the "eaters." Organisms that eat or use other organisms to get energy are called **consumers**.

Cellular respiration is a chemical reaction that occurs in the cells of organisms. During cellular respiration, the chemical energy in sugars is released so that it can be used by the organism for growth, movement, survival, and reproduction. When you breathe, your body uses the oxygen you inhale for cellular respiration. You breathe out carbon dioxide that forms during the reaction.



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Types of Consumers

Consumers are sorted into categories based on how they get energy.

Herbivores eat plants. Deer, beavers, rabbits, and caterpillars are herbivores.

Carnivores catch, kill, and eat other animals. Carnivores include otters, bobcats, hawks, snakes, and predatory fish.

Omnivores eat both plants and animals. Many animals are omnivores, including wood ducks, bears, raccoons, and humans.

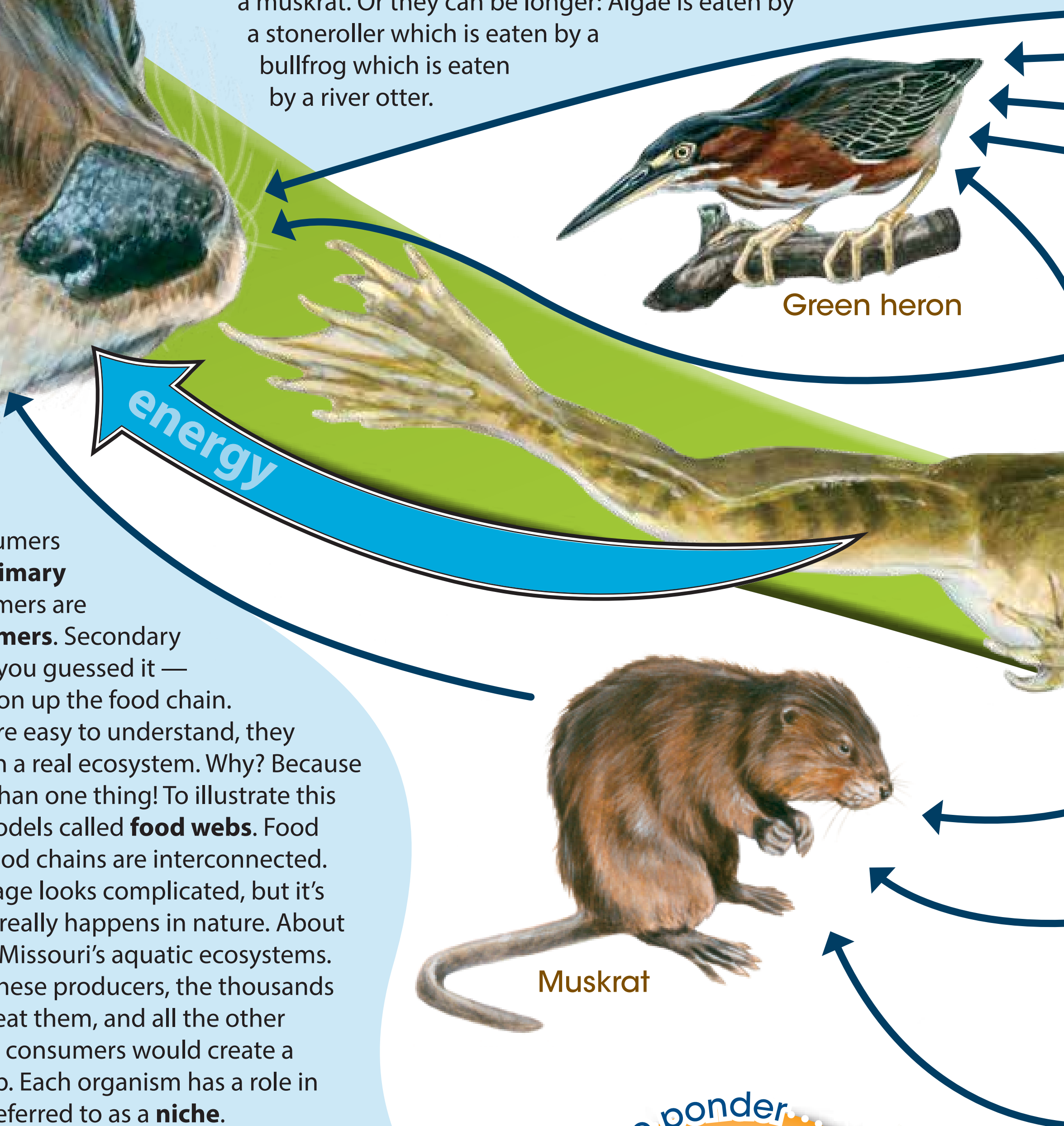
Scavengers eat dead plants and animals. In doing so, scavengers break down dead organisms into smaller bits and pieces.

Decomposers get energy by breaking down dead organisms into simple atoms and molecules.

FOOD WEBS

show how energy flows among organisms.

A **food chain** shows how energy moves from the sun to a producer and through various consumers. It's like a road map of who eats whom. Food chains can be short: Arrowhead plant is eaten by a muskrat. Or they can be longer: Algae is eaten by a stoneroller which is eaten by a bullfrog which is eaten by a river otter.



Ecologists sometimes categorize consumers by the order in which they occur in a food chain. Consumers that eat plants are called **primary consumers**. Primary consumers are eaten by **secondary consumers**. Secondary consumers are eaten by — you guessed it — tertiary consumers. And so on up the food chain.

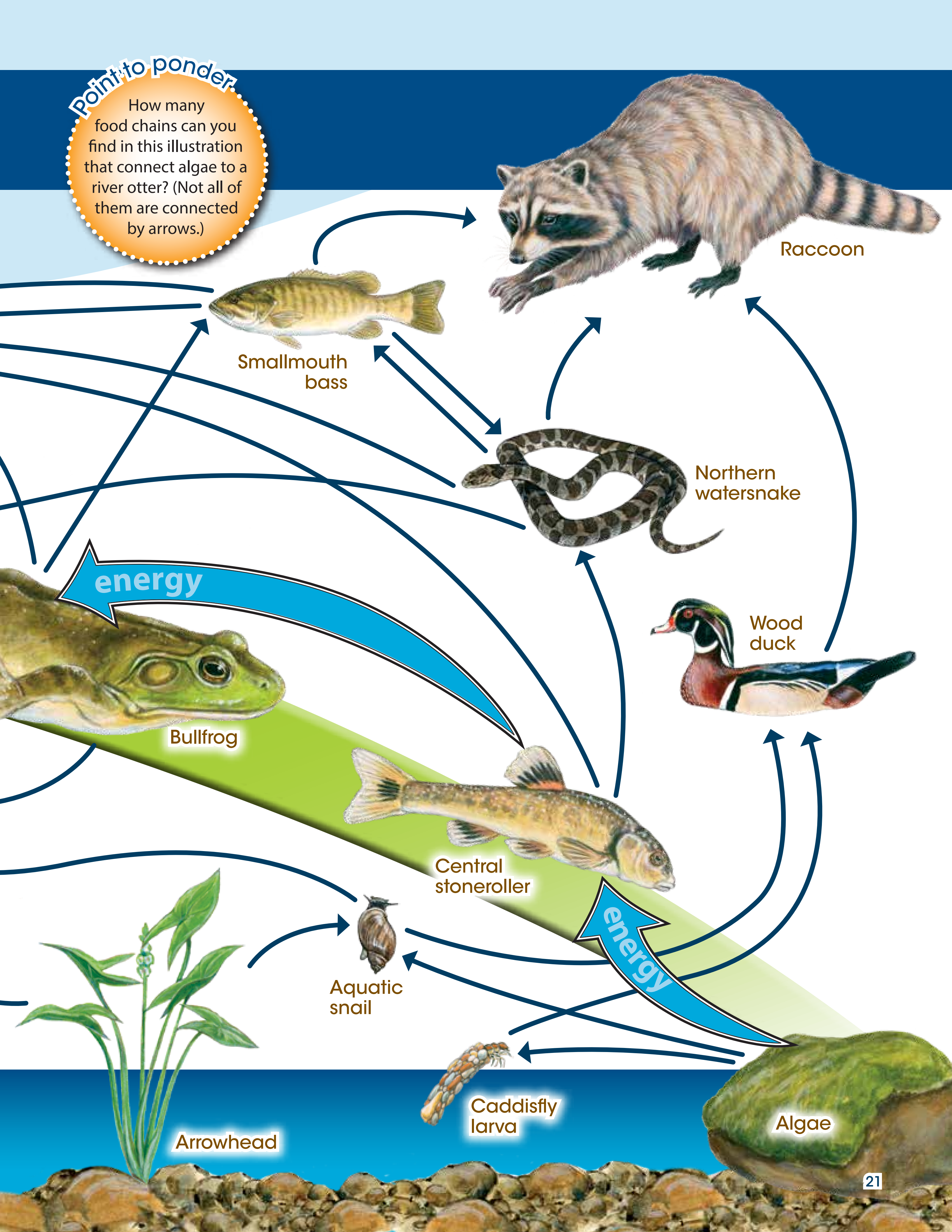
Although food chains are easy to understand, they don't show what happens in a real ecosystem. Why? Because most consumers eat more than one thing! To illustrate this fact, biologists construct models called **food webs**. Food webs show how different food chains are interconnected.

The food web on this page looks complicated, but it's nothing compared to what really happens in nature. About 1,500 kinds of plants live in Missouri's aquatic ecosystems. Drawing lines between all these producers, the thousands of primary consumers that eat them, and all the other consumers that eat primary consumers would create a really complicated food web. Each organism has a role in the ecosystem. This role is referred to as a **niche**.

Up until now, we've left out a very important part of any food web: scavengers and decomposers. Because every organism eventually dies, every organism in a food web can also be connected with one or more scavengers or decomposers. Scavengers and decomposers break organisms down into smaller pieces and eventually into atoms and molecules that can be reused by plants during photosynthesis. What goes around comes around.

Point to ponder

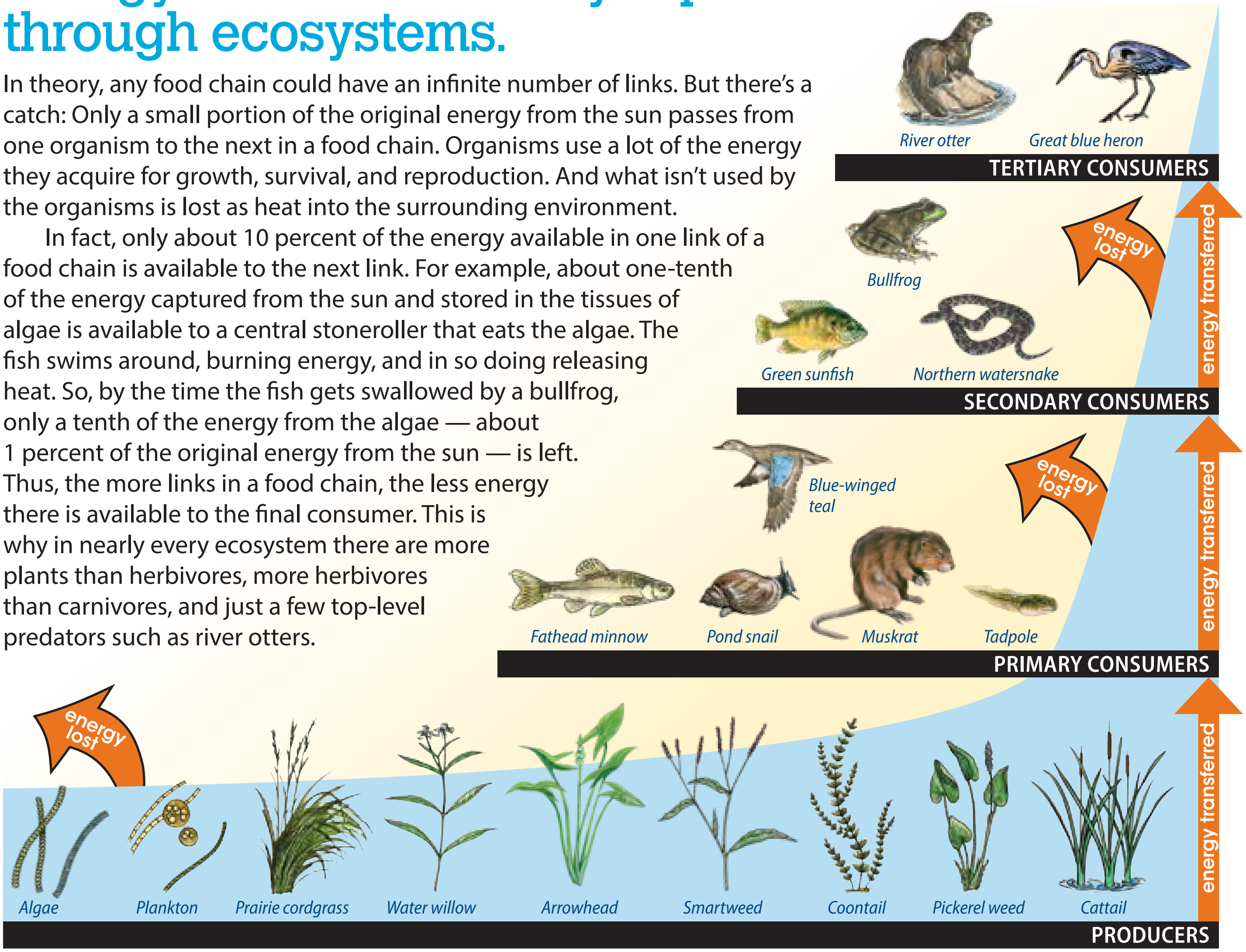
This crayfish is a decomposer. How does it get the energy it needs to survive?


Point to ponder
How many food chains can you find in this illustration that connect algae to a river otter? (Not all of them are connected by arrows.)
Raccoon
Smallmouth bass
Northern watersnake
energy
Wood duck
Bullfrog
Central stoneroller
energy
Aquatic snail
Caddisfly larva
Algae
Arrowhead

Energy makes a one-way trip through ecosystems.

In theory, any food chain could have an infinite number of links. But there's a catch: Only a small portion of the original energy from the sun passes from one organism to the next in a food chain. Organisms use a lot of the energy they acquire for growth, survival, and reproduction. And what isn't used by the organisms is lost as heat into the surrounding environment.

In fact, only about 10 percent of the energy available in one link of a food chain is available to the next link. For example, about one-tenth of the energy captured from the sun and stored in the tissues of algae is available to a central stoneroller that eats the algae. The fish swims around, burning energy, and in so doing releasing heat. So, by the time the fish gets swallowed by a bullfrog, only a tenth of the energy from the algae — about 1 percent of the original energy from the sun — is left. Thus, the more links in a food chain, the less energy there is available to the final consumer. This is why in nearly every ecosystem there are more plants than herbivores, more herbivores than carnivores, and just a few top-level predators such as river otters.



KEEP Discovering

To see decomposition in action, start an earthworm farm. To learn how, search for "vermicomposting" on the Internet. Once you've spent several months feeding your squirmy tenants kitchen scraps — vegetable peels, apple cores, coffee grounds, etc. — you'll begin to notice the worms in your farm are increasing in number. (If you have more worms than space, the big ones make good fishing bait.) You'll also notice lots of black "soil." Gardeners call this stuff castings. You'll probably call it worm poop. Whatever its name, it's great for your garden because it's full of nutrients the worms have recycled from the kitchen scraps they have eaten.

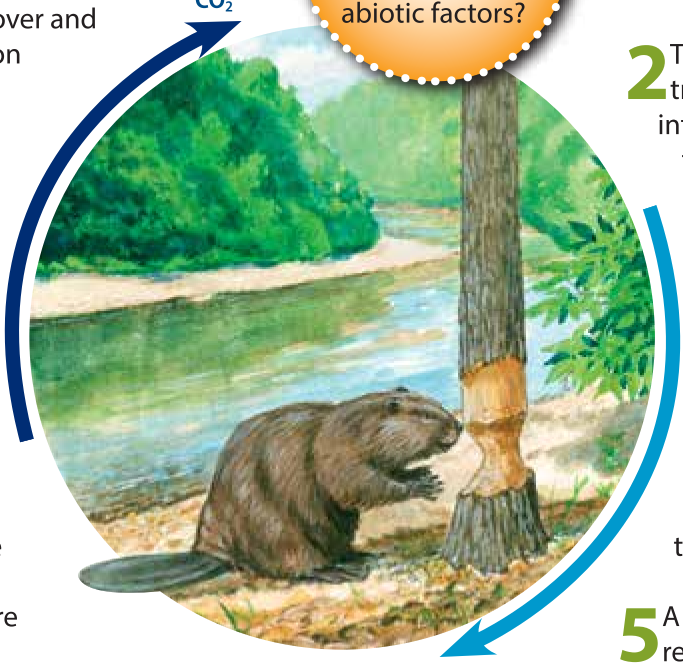
Atoms are recycled over and over again.

Unlike energy, atoms don't make a one-way trip through ecosystems. They get reused, rearranged, and recombined over and over and *over* again. The carbon atoms in your body may once have been part of a chunk of limestone on the ocean floor, the fur of a woolly mammoth, or the feather of an eagle. Here's a simple illustration of how carbon atoms are recycled among living and nonliving parts of an ecosystem.

The nonliving parts of an ecosystem are called **abiotic factors**. Water, air, soil, sunlight, and minerals are examples. The living or once-living parts of an ecosystem are called **biotic factors**. Animals, plants, fungi, and other organisms are all biotic factors.

Point to ponder

In the illustration below, can you find the biotic and abiotic factors?



1 A cottonwood tree absorbs carbon dioxide from the environment.

2 Through photosynthesis, the tree turns the carbon dioxide into sugars. It stores some of these sugars in tissues such as bark.

3 If the tree is eaten by a beaver, some of the sugar molecules in the tree are taken into the beaver's body.

4 The beaver converts the sugars to energy through cellular respiration.

5 A byproduct of cellular respiration is carbon dioxide, which the beaver exhales into the environment.

MAKE THE Connection

A pond's most important producers are microscopic plants called **phytoplankton**. Billions of these tiny plants give the water in some ponds a greenish tint. Phytoplankton, like all producers, need more than sunlight, water, and carbon dioxide to grow. They also require molecules such as nitrogen and phosphorus. These molecules, which a plant scientist might call **nutrients**, wash from surrounding soil and dissolve in the water. In areas with high soil fertility there are more nutrients available, and this can contribute to more phytoplankton.

Fisheries biologists typically recommend stocking a combination of largemouth bass and bluegill in a new pond in Missouri. Where soil fertility is high, biologists recommend stocking 100 bass and 500 bluegill for each acre of surface water. Where soil fertility is low, biologists recommend 50 bass and 250 bluegill.

Using what you know about producers, consumers, and food chains, explain why there is a difference in stocking rates based on soil fertility.

4 INTERACTIONS

BIG IDEAS

- Interactions shape the numbers and kinds of organisms found in an ecosystem.
- Interactions can be categorized by the costs and benefits to the organisms involved.
- Specialized structures help organisms survive the interactions they face.
- Interactions can limit the growth of populations.

In a quiet pool on an Ozark stream, thousands of mayflies rise to the water's surface to transform from swimming larvae into flying adults. As the insects struggle to shed their larval skins, fish cruise in for a feast. In seconds, the morning stillness is broken by the *pop … pop … pop* of bluegill and green sunfish slurping mayflies, each fish competing fiercely with the others to swallow as many insects as possible before the supply of food runs out.

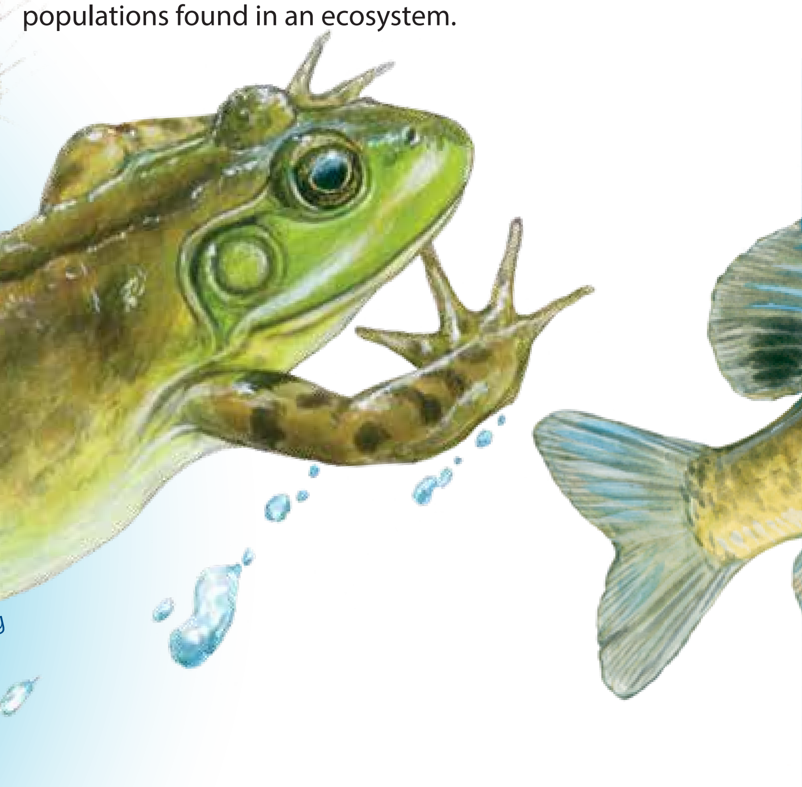
On a nearby gravel bar, a mink wades ashore, drops a dead bullfrog from her mouth, and shakes water from her fur with the enthusiasm of a Labrador retriever. A successful night of hunting will mean full bellies for the mink's kits. It also will mean that tonight's chorus of frogs will be one croak quieter.

Along the stream's edge, squadrons of bumblebees patrol forests of wild blue irises. For an iris, a bumblebee is a delivery pilot, transporting pollen from flower to flower, thus ensuring future blooms. For a bee, an iris is a grocery store, providing nectar and pollen to make honey, thus ensuring food for a future generation of bumblebees.

Relationships such as these abound in nature. In this chapter we'll explore how interactions affect the populations found in an ecosystem.

Did you know?

Mink feel so at home in the water, they have been seen floating down rivers curled up in balls, apparently asleep.



Interactions shape the numbers and kinds of organisms found in an ecosystem.

Why do certain organisms live in certain places? Why, for example, don't you find rainbow trout living in a muddy farm pond, but channel catfish seem to do just fine there? It's a seemingly simple question, but the answer is more complicated than you might expect.

Part of the answer lies with the fact that every organism can tolerate only a certain range of environmental conditions. Trout can't tolerate muddy water; channel catfish can.

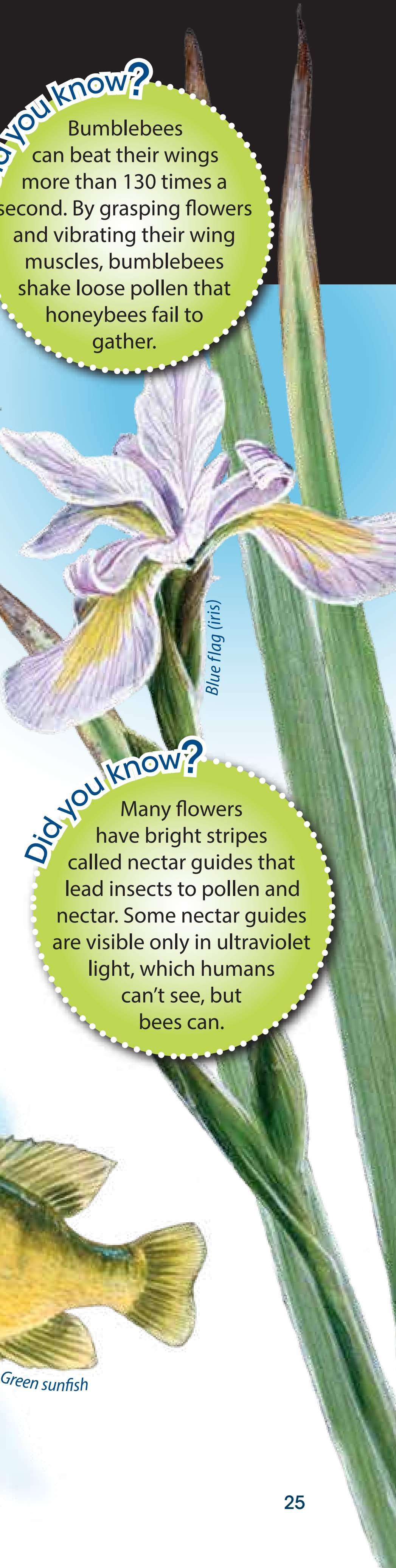
Another part of the answer has to do with the fact that every organism needs certain things to grow, survive, and reproduce. Biologists refer to these necessities of life as **resources**. For a mink, resources include water to drink, food — such as frogs — to eat, and dens in which to live and raise a family. If those resources aren't found in a certain place, you won't find mink there, either.

The last part of the answer has to do with the fact that no living thing exists all by itself. Other organisms occupy the same place at the same time. And the interactions among all of these organisms shape the growth, survival, and reproduction of each.

Did you know?

Bumblebees can beat their wings more than 130 times a second. By grasping flowers and vibrating their wing muscles, bumblebees shake loose pollen that honeybees fail to gather.

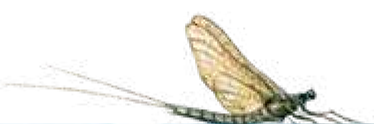
Bumblebee



Blue flag (iris)

Did you know?

Many flowers have bright stripes called nectar guides that lead insects to pollen and nectar. Some nectar guides are visible only in ultraviolet light, which humans can't see, but bees can.



Mayfly

Bluegill

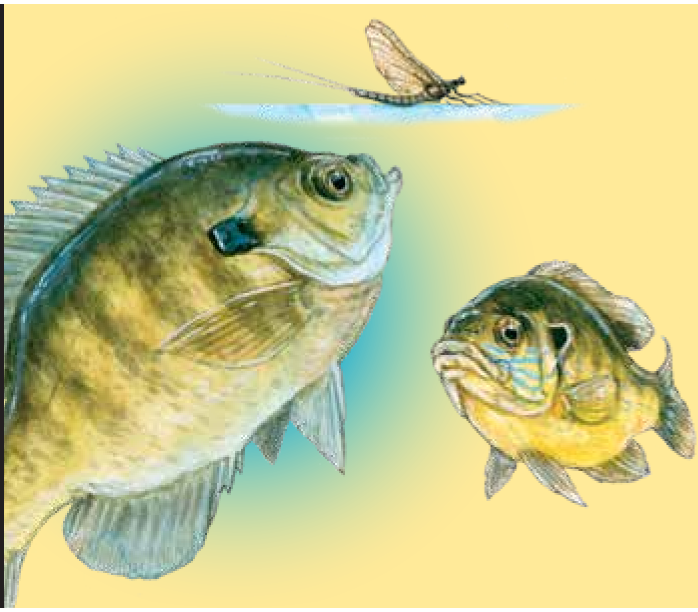
Green sunfish

Did you know?

The green sunfish is Missouri's most widely distributed fish, found in nearly every stream in the state.

Interactions can be categorized by the costs and benefits to the organisms involved.

COMPETITION



Competition

Competition occurs when two or more organisms try to use the same limited resource. For example, insects make up a large part of the diets of both bluegill and green sunfish, and these fish compete with each other for food. Each time one fish slurps down an insect, fewer insects are left for the other fish.

One important idea in biology is known as the **competitive exclusion principle**. It predicts that if two species compete for exactly the same set of resources in the same place at the same time, one species will be better at getting the resources than the other. Because of this, the more competitive species will grow faster, survive better, and produce

EXPLOITATION

Exploitation

As we learned in Chapter 3, consumers — because they can't make their own food — must eat other organisms to obtain energy and nutrients. **Predators**, such as mink, get energy by catching **prey**, such as frogs. Herbivores, such as beavers, get energy by eating plants. **Parasites**, such as leeches, get energy by feeding on the blood, fluids, or other parts of another organism (the host), usually without killing the host.

Although each of these interactions is slightly different, they all have one thing in common: One organism benefits from the interaction while the

MUTUALISM

Did you know?

A bumblebee may visit more than 500 flowers each day.

Mutualism

Many interactions in nature benefit both participants. Bumblebees disperse an iris's pollen in return for a meal of nectar. Win, win. The bacteria living in a mink's stomach help break down the food a mink eats into nutrients. In return, the bacteria keep a few nutrients for themselves and get a warm place to live. Win, win. **Mutualism** is a type of interaction in which both organisms benefit.

Just like the other types of interactions we've studied, mutualism helps shape the numbers and kinds of organisms that live in an ecosystem.

Point to ponder

Can you think of examples of interactions in which one organism benefits and the other is unaffected?

more offspring. The less competitive species — with fewer and fewer resources for growth, survival, and reproduction — will eventually die off.

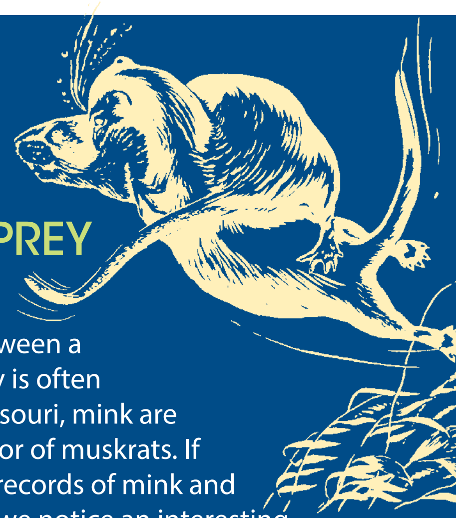
Instead of competing for the same resources, species usually divide them up or use them in slightly different ways. Biologists call this **resource partitioning**. Bluegill have tiny mouths and tend to sip up small insects. Green sunfish have larger mouths and tend to eat larger insects and small fish. In this way, the two fish divide up resources and avoid competitive exclusion.

By causing species to divide up and use resources in different ways, competition shapes the numbers and kinds of organisms found in any given ecosystem.

other organism is harmed. Biologists often group these kinds of interactions together and call it **exploitation**.

By killing or weakening the organisms they eat, predators, herbivores, and parasites can affect the kinds and numbers of prey, plants, and hosts that live in an ecosystem. For example, smallmouth bass, a predatory fish that lives in cold, clear Ozark streams, preys heavily on crayfish. By doing so, bass keep the numbers of crayfish lower than they would be if the fish weren't around. Likewise, shortages of prey, plants, and hosts can limit the numbers of predators, herbivores, and parasites that live in an ecosystem.

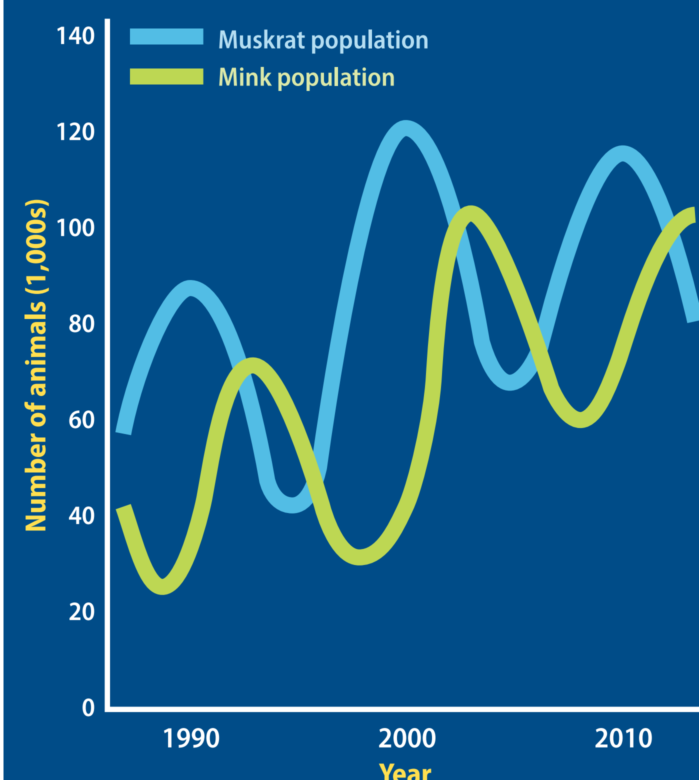
There would be far fewer irises if there weren't any bumblebees to transport the flowers' pollen. And some organisms are so closely linked by mutualism that neither organism could exist without the other. Lichens, those mossy-looking organisms that grow on rocks and bark, are actually two separate organisms. One is a fungus that gathers nutrients from the surface on which it grows. The other is an algae that uses photosynthesis to produce energy. Because organisms need both nutrients and energy, neither organism in a lichen could survive without the other.



PREDATOR-PREY CYCLES

The relationship between a predator and its prey is often closely linked. In Missouri, mink are an important predator of muskrats. If we look at trapping records of mink and muskrats over time, we notice an interesting pattern. Every 10 years, the number of muskrats caught by trappers reaches a peak but then quickly plummets. Likewise, the number of mink grows and shrinks every 10 years, but the peaks and valleys shown by mink happen three years after those shown by muskrats. Why?

When there are few predators, the muskrat population grows quickly. Once there are plenty of muskrats to eat, the mink population begins to grow. Eventually, mink begin to eat muskrats faster than muskrats can reproduce, and the muskrat population crashes. When prey becomes scarce, the mink population declines as well. Biologists call these interrelated population peaks and valleys **predator-prey cycles**.



Specialized structures help organisms survive the interactions they face.


Striped skunk

All organisms have specialized structures and behaviors that help them survive the environment in which they live. The gills of a fish, the wings of a bird, the thumbs of a person — all of these are **specialized structures**.

Many organisms have specialized structures that help them in the day-to-day interactions they have with other organisms. For example, predators have a stunning arsenal of structures to help them find and capture prey. Nearly every part of a catfish's body — from its whiskery head to its slippery tail — is covered with taste buds. This helps the fish find food in dark, murky water. A great blue heron's long neck and daggerlike bill help the bird spear fish, frogs, and snakes in shallow pools. Some species of frogs have long, sticky tongues that they can fling out of their mouths to snag unsuspecting insects.


Great blue heron


Ozark sculpin

Prey organisms have structures that help them avoid being eaten. Bottom-dwelling fish called sculpins have colors and patterns that help them blend in with the bottom of the stream. This camouflage makes it hard for predators to find them. Turtles have bony shells that protect them from attack. And some prey animals use noxious chemicals to keep predators at bay. Monarch butterflies, skunks, and bumblebees advertise their poor taste, foul smell, or stinging behinds with bold colors and patterns called **warning coloration**.

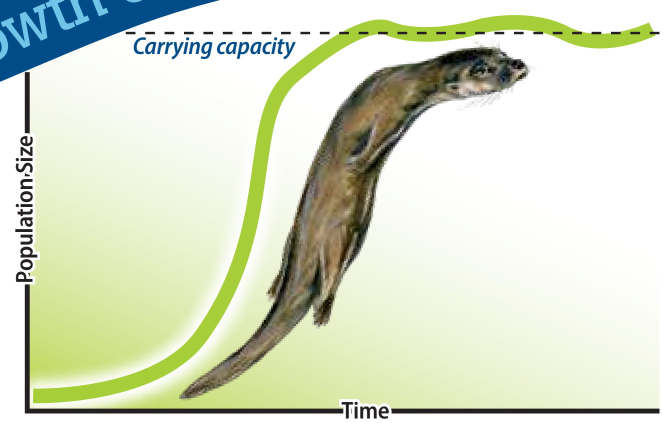
It isn't just animals that use specialized structures. Many plants have such structures to attract pollinators, repel predators (herbivores), and disperse their seeds. Most flowers are brightly colored, scented, or contain nectar to attract pollinators such as bees, butterflies, and hummingbirds. If you've ever picked blackberries, you know that thorns are a good defense for keeping plant-eating animals such as deer from eating a blackberry plant's foliage. The berries themselves contain seeds, which birds and other animals disperse when they eat the berries and then pass the hard-to-digest seeds through their bodies.

Interactions can limit the growth of populations.

In the late 1800s, habitat destruction and unregulated trapping nearly wiped out Missouri's river otters. A 1936 survey found only a handful of otters surviving in the swamps of the Bootheel. In the 1980s, the Conservation Department started releasing otters from Louisiana into the rivers and wetlands of the Show-Me State. Since those releases, the otter population has grown from 70 to more than 15,000, and the furry, torpedo-shaped mammals now flourish in nearly every aquatic nook and cranny of the state.

This illustrates an important idea in ecology: With abundant resources, populations can grow quickly. In fact, if Missouri's otter population were allowed to grow unchecked, in just over a century there would be nearly 9 quadrillion otters!

Obviously, this could never happen. There isn't enough food, space, water, den sites, and other resources to support that many otters. As the otter population grows, competition for these resources gets fierce, and some otters don't find enough resources to survive. This causes the otter population to stop growing and reach **carrying capacity**, the population size a given area can support at a given time. Things that limit how large a population can grow are called **limiting factors**. Because interactions such as competition and exploitation affect an organism's growth, survival, and reproduction, they are important limiting factors that affect a population's size.



KEEP Discovering

The next time you go fishing at a pond, bring along an assortment of lures and baits. Be sure to bring a few lures that look like insects, a few that look like fish, and a few that make noise or wiggle when you reel them in. Also pack some live worms or baits that give off a smell. Keep track of what kinds of fish you catch with each type of lure. Do you notice a pattern? If so, what do you think might explain this pattern?

MAKE THE Connection

Picture yourself at your favorite fishing hole. You've caught a limit of fish, and it's time to head home. You gather your equipment and carefully pick up litter. Your bait bucket still contains live crayfish or minnows. Not wanting to waste these critters, you release them into the water. Whoops, big mistake! You may have just introduced invasive, nonnative animals into your favorite stream.

Biologists have known for years that "bait bucket introductions" are one of the most common ways of spreading aquatic invaders. Bait bucket introductions occur when anglers dump live bait into a water body where the bait wasn't originally found. The solution to bait bucket introductions is simple. Anglers shouldn't dump their leftover bait in Missouri waters. Instead they should take their bait home to use on a future fishing trip or dispose of it in a sealed container in the trash.

Missouri's waters are home to more than 200 species of native fish, 65 species of native mussels, and at least 33 species of native crayfish. Nonnative species, such as Asian carp, zebra mussels, and rusty crayfish, are invading our waterways at alarming rates and have the potential to push out native species.

Given what you've learned about interactions among organisms, explain why nonnative species have the potential to eliminate native species from an ecosystem.

5 BIODIVERSITY

BIG IDEAS

- Biodiversity refers to the variety of species, genes, or ecosystems in a given area.
- Biodiversity offers clues to an ecosystem's health.
- Habitat destruction, pollution, overharvesting, invasive species, and changes in climate threaten biodiversity.
- Biodiversity undergoes a series of changes following a disturbance.

Imagine donning a snorkel and taking a cool summer swim down a clear Ozark stream. If you paid close attention, you would be amazed by the variety of life existing just beyond your mask: minnows and darters of every color schooling in the calm water behind a boulder; squiggly insects of every shape clinging to algae-covered stones; camouflaged crayfish, sculpins, and hellbenders creeping out of rocky crevices; life everywhere you look.

This multitude of creatures — along with all the plants, bacteria, and other living things in the stream — makes up a **biological community**. In this chapter we'll learn how biologists measure and compare communities, examine why variety is important for healthy communities, and explore how communities change over time.

Did you know? Worldwide, biologists have named 1.8 million species, and they estimate that 30 million more likely exist. That's a lot of biodiversity!

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Biodiversity refers to the variety of genes, species, or ecosystems in a given area.

When it comes to freshwater fishes, Missouri is one of the fishiest places on Earth. Nearly 200 species — from snakelike eels to whiskery catfish — swim in the Show-Me State's waters. Yet Missouri's amazing variety of organisms isn't limited to those with fins. About 70 kinds of mammals, 400 kinds of birds, 100 kinds of reptiles and amphibians, and 18,000 kinds of insects run, fly, slither, flutter, buzz, burrow, and scurry through Missouri. Nearly 3,200 kinds of plants grow here, and don't get us started on how many fungi, bacteria, and other microscopic organisms we may have! These species make up the biological diversity, or **biodiversity**, of our state. Biodiversity can be examined at three different levels: species diversity, genetic diversity, and ecosystem diversity.

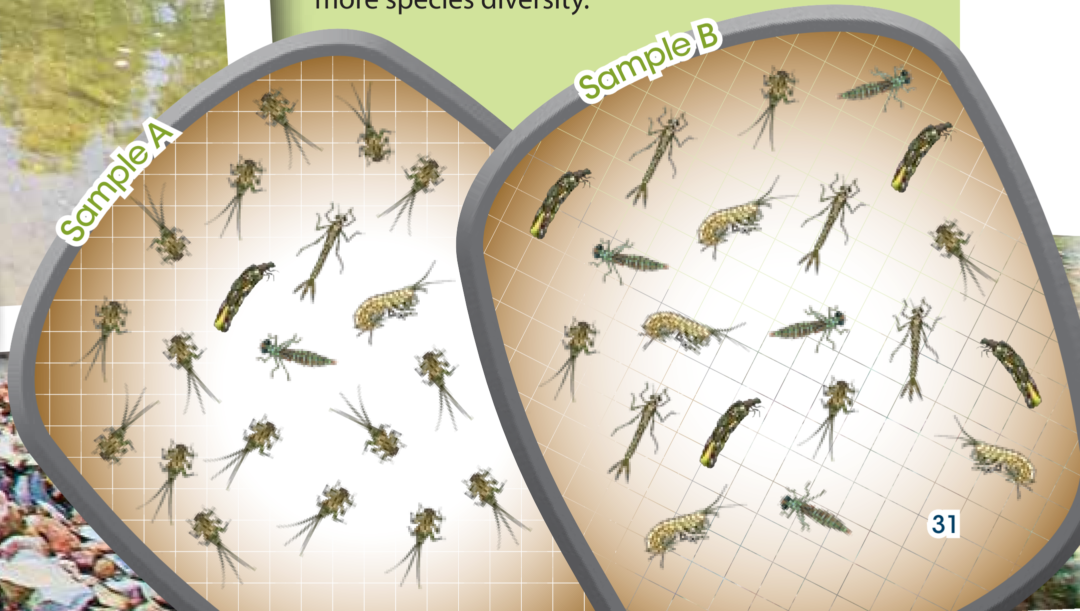
SPECIES Diversity

One common way to measure biodiversity is to count the number of species living in a particular area. Biologists call this measurement **species richness**. Species richness, however, describes only part of an area's species diversity. For the full picture, biologists determine how abundant each species is compared to all the others in a community. This measurement is known as **relative abundance**.

Species diversity is measured by both species richness and relative abundance. To illustrate, let's compare two samples of macroinvertebrates found in two sections of a stream. **Macroinvertebrates** are organisms without backbones that are found in water. As you can see from these dip nets, both stream sections yielded a sample of 20 macroinvertebrates. Each sample contains five species, thus both have equal amounts of species richness. In Sample A, however, one species is much more abundant than the other four species, while in Sample B, all five species are equally abundant. Based on this evidence, a biologist would say that the stream section represented by Sample B has more species diversity.

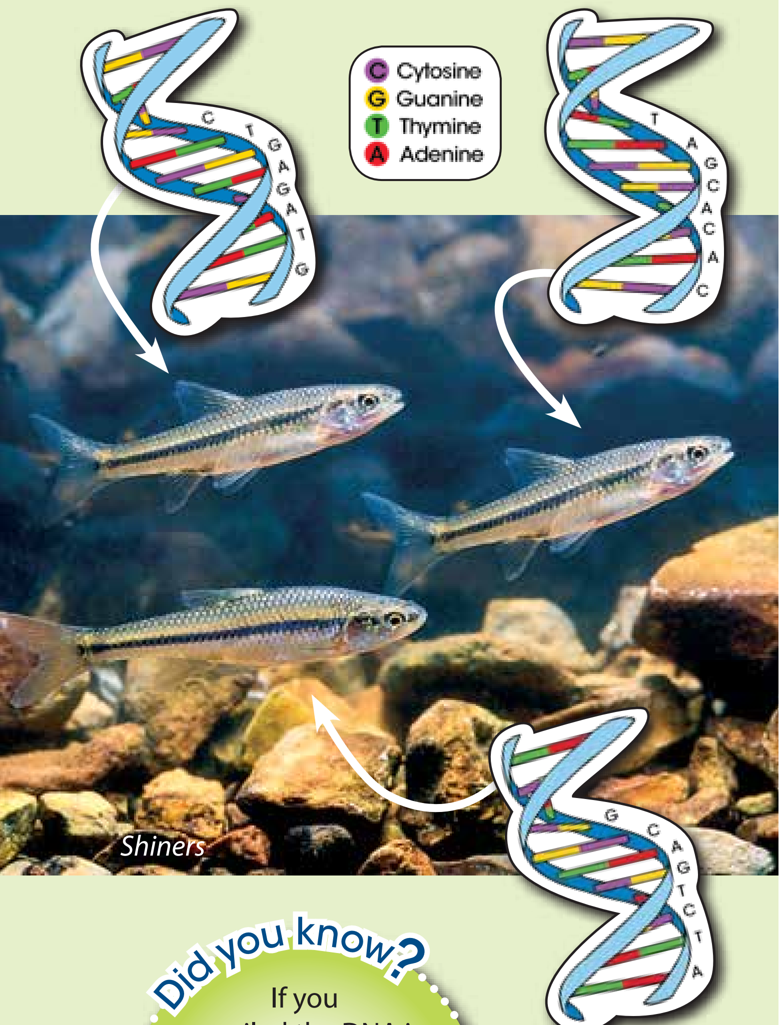
Did you know?

The human body is a model of biodiversity. No matter how well you wash, your body has dozens of species of animals, fungi, protists, and bacteria living on and in it. In fact, your body contains just as many (if not more) nonhuman cells as human cells.



GENETIC Diversity

Genetic diversity refers to the variety of genes found in the individuals of a population. **Genes** are sections of DNA that affect an organism's outward appearance, behaviors, and abilities — in short, the organism's traits. The more genetically diverse a population is, the more variety there will be in the traits of its members. Variety is important for a population to survive. If all the members of a population had similar traits, the population would be less likely to survive a disease outbreak or a change in its habitat. But if the members of a population have a variety of traits, there's more of a chance that some members would survive.



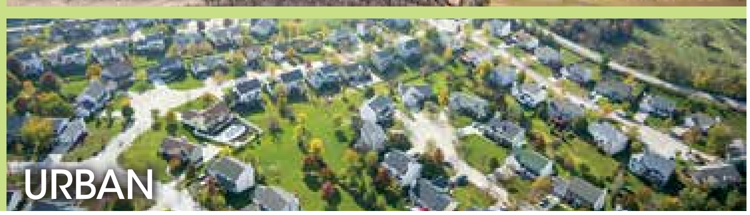
Shiners

Did you know?

If you uncoiled the DNA in every cell in your body, it would stretch 15 billion kilometers — about the distance from Earth to Pluto and back.

ECOSYSTEM Diversity

Ecosystem diversity refers to the variety of ecosystems that exist within a larger region such as a conservation area or watershed. Some species, such as white-tailed deer, are able to survive in many kinds of ecosystems. These species are known as **generalists**. Other species, such as hellbenders, can survive in only one kind of ecosystem. These species are known as **specialists**. A greater variety of ecosystems provides habitats for a greater variety of species, both generalists and specialists.



Biodiversity offers clues to an ecosystem's health.

To many people, biodiversity is priceless, worth protecting for its own sake. But biodiversity also provides measurable benefits to humans, other organisms, and the Earth as a whole.

Biodiversity offers sources of medicine. Aspirin was originally made from the bark of a willow tree. A cure for cancer may be out there, hidden in the cells of some organism.

Biodiversity provides a variety of foods for humans and other organisms. Ancestors of today's tomatoes, which are eaten throughout the world in ketchup, salsas, and pasta sauces, were originally found growing wild in North America.

Biodiversity creates opportunities for outdoor recreation. People like to visit places that have a great deal of biodiversity to hike, camp, hunt, fish, watch birds, or engage in other outdoor activities.

Perhaps most importantly, biodiversity offers clues to an ecosystem's health. In general, the greater the biodiversity, the healthier the ecosystem. Why? Ecosystems contain a variety of species connected to each other through many kinds of interactions. In an ecosystem with poor biodiversity, a shortage or disappearance of one species may have a dramatic effect on other species in the ecosystem. For example, if all of the predators in an ecosystem depended upon a single species for prey, the disappearance of that prey species would eventually lead to the disappearance of all of the predators. However, if the same ecosystem had more biodiversity — and thus a greater variety of prey — a shortage or disappearance of a single prey species wouldn't have as large an effect on the predators. Thus, greater biodiversity provides an ecological "cushion," so that the loss of one species doesn't necessarily cause the loss of others.

Point to ponder

Which is stronger, a rope composed of five strands or a rope composed of 10 strands? Why? Now think of an ecosystem as a rope and each species in the ecosystem as a strand of that rope. Which ecosystem is stronger, one with five species or one with 10 species? Why?

Habitat destruction, pollution, over harvest, invasive species, and changes in climate threaten biodiversity.

Habitat Destruction

Habitat destruction and **habitat fragmentation** — the carving of large blocks of habitat into smaller, scattered pieces — are the biggest threats to biodiversity. Swamps and bottomland forests once covered nearly 2.5 million acres of Missouri's Bootheel. Today, about 800,000 acres of bottomland forests remain *in the entire state*, in places such as Mingo National Wildlife Refuge and Big Oak Tree State Park. Species that depend on this soggy habitat — such as toothy alligator gars, towering bald cypress trees, and colorful cerulean warblers — have decreased in numbers as well.

Mingo National Wildlife Refuge

Pollution

Pollution can come in many forms, and it affects the air, land, and water. Biologists from the Department of Natural Resources and Conservation Department investigate nearly 400 cases of fish kills each year. Many of the cases are caused by natural conditions, such as low oxygen in the water or diseases. But some are caused by pollution from chemicals, fertilizers, sewage, animal wastes, and other pollution sources. Pollution kills many aquatic organisms and makes fish unsafe to eat. To see the most recent fish consumption advisory for Missouri's waters, visit **on.mo.gov/1XcBN7T**.

Fish kill

Overharvesting

Some species are hunted, fished, or harvested to extinction — or nearly so. Lake sturgeon, a species that once swam near wading dinosaurs, barely survived the arrival of human beings. In the early 1900s, people developed a taste for sturgeon and their eggs, steamboats burned the fish's oily flesh for fuel, and processing plants turned thousands of sturgeon into fertilizer. By the mid 1900s, overharvest had nearly wiped out lake sturgeon in Missouri. Fishing laws, restocking efforts, and habitat improvements are bringing sturgeon back from the brink of extinction, but it's unlikely their numbers will ever be as high as they once were.

Lake sturgeon

Did you know?

Lake sturgeon can live for 150 years, reach 8 feet long, and weigh 300 pounds. The shark-like fish use their toothless, stretchy mouths to vacuum up mollusks and insects from the muck at the bottom of rivers.

Point to ponder

How many plants and animals live on the campus of your school? Are any of them affected by threats to biodiversity?

Invasive Species

Wherever humans have traveled, we have accidentally or deliberately brought other species with us. Nonnative plants and animals are often **invasive**, adapting quickly to new locations and pushing out native species. Take, for instance, the zebra mussel. Zebra mussels are native to the Caspian Sea. The fingernail-sized mollusks hitched a ride on ships and turned up in waters near Detroit in 1988. Since then, the mussels have spread down the Mississippi and Missouri rivers into the Show-Me State.

Female zebra mussels can produce 1 million eggs each year, allowing them to quickly blanket habitats and prevent native mussels from getting nutrients. Zebra mussels feed on plankton, which puts them in direct competition with native mussels and young bass and bluegill. And large colonies of zebra mussels can remove enough oxygen from the water to cause fish kills.

Zebra mussel

Did you know?

At a power plant on Lake Erie, zebra mussels went from undetectable levels in 1988 to 700,000 per square meter in 1989.

Changes in Climate

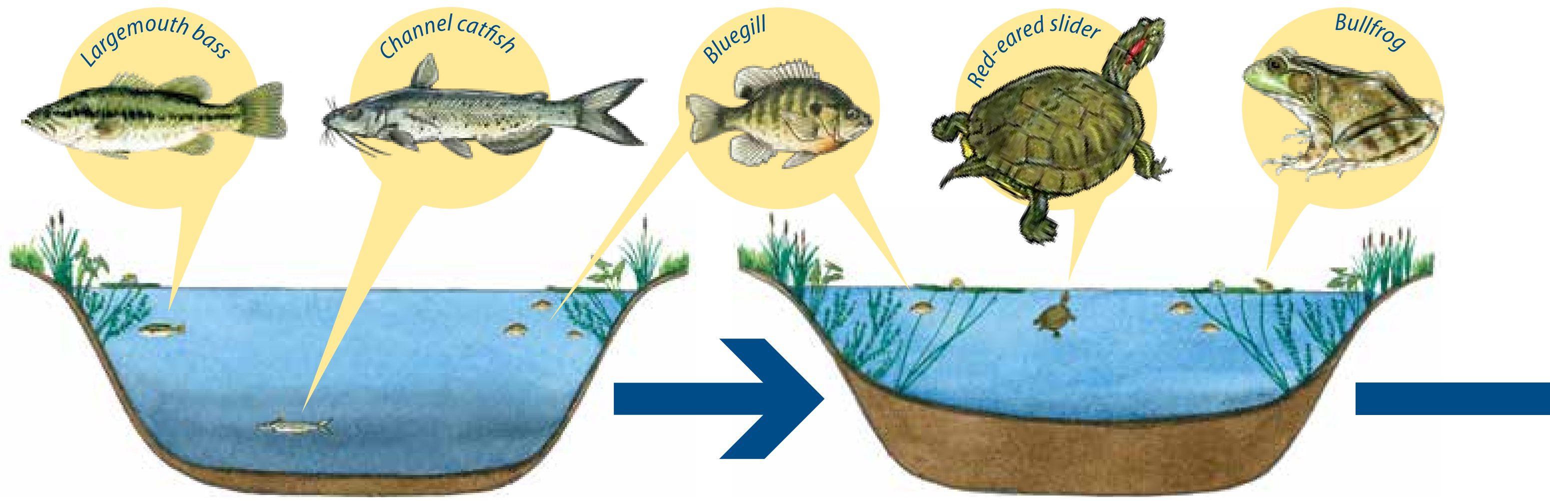
Every organism is adapted to live within a particular range of environmental conditions. If abiotic factors such as temperature, precipitation, or oxygen concentration shift outside the range required by a particular species, the existence of that species in that particular habitat becomes impossible. Many scientists believe that changes in global climates have wide-ranging effects on environmental conditions and are expected to cause population declines in species ranging from tropical corals to Midwestern mammals.

American toad

KEEP Discovering

How many species live in your schoolyard, backyard, or neighborhood park? One way to find out is to do a **bioblitz**, a rapid but intense survey to record all the living species in a designated area. Many bioblitzes last 24 hours, but for smaller areas, a few hours is often adequate. To undertake a bioblitz, gather a few friends and plenty of field guides to record the plants and animals of your region. If your ID skills aren't the best, don't worry. Enlist the help of adults — teachers, biologists, naturalists, and conservationists — who are skilled at identifying plants and animals. Once your team has gathered, start the stopwatch and spread out across the landscape. Look closely! It's easy to miss small creatures such as insects or overlook a new species of grass because it blends in with all the other green plants. When time is up, gather the team, compare notes, and tally up how many species were found. You may be surprised at the total. Even if you aren't, bioblitzes are a fun way to get a snapshot of the biodiversity around you.

Biodiversity undergoes a series of changes following a disturbance.



A young pond has plants growing around its edge but few growing in its center because the water is too deep.

As time goes by, the pond begins to fill with sediment and organic material. The pond becomes smaller and shallower, allowing new plants and animals to live there.

Pond Succession

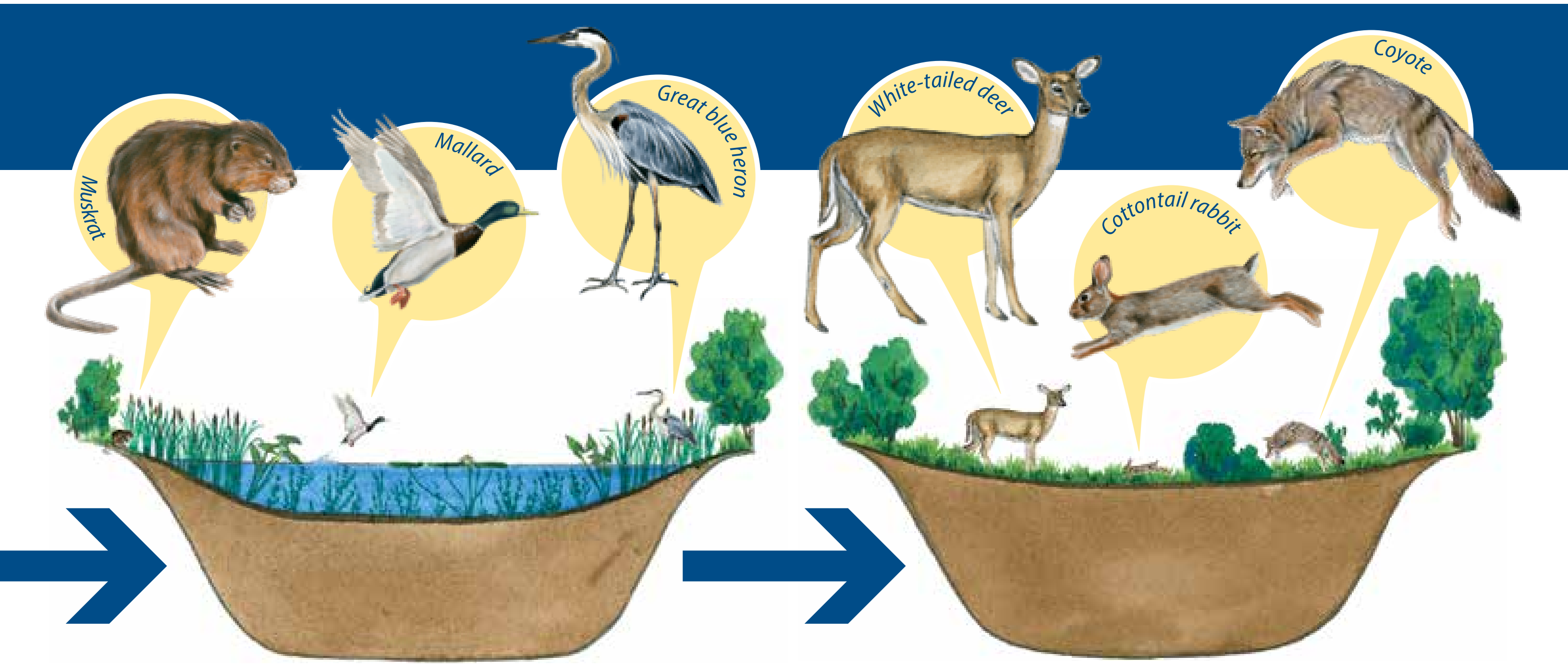
To the casual observer, nothing seems to change in a community. A pond seems surrounded by the same cattails and filled with the same fish that were there last year or even 20 years before. Although some organisms die and others are born, cattails replace cattails and bass replace bass. A careful observer, however, will notice that communities are constantly changing.

Take our pond for example. As water runs downhill through the pond's watershed, it picks up small bits of soil, seeds, and anything else that can be moved. Over time, sediments fill in the pond. Decaying plants and animals sink to the bottom of the pond, adding to the sediment and making it more fertile. As the pond gets more shallow, plants take root and begin to take up more space. Seeds from new areas are brought to the pond by wind, water, and animals, and new species slowly replace the ones that were there before. Over time, the pond gets shallower and shallower, changing into a wetland, then a meadow, then a forest.

This sequence of changes is called **succession**, or the replacement of one biological community by another over time. Disturbances cause succession. To a biologist, a **disturbance** is any significant change in the typical environmental conditions of a community. Abiotic forces — such as fires, tornadoes, ice storms, and floods — create disturbance. Biotic factors — such as disease, pest outbreaks, predation, and human activities — also can result in disturbance.

After a disturbance, the first species to show up form the **pioneer** or **early successional community**. By being the first to colonize a new habitat and by growing quickly, pioneer species often inhibit the growth of other species. Their dominance, however, is usually short-lived. Pioneer species gradually change the environment in which they live, often making it less suitable for their own existence. Plants, for example, create shade, redistribute nutrients, alter moisture levels, and hold the soil in place. These changes create favorable conditions for new species. This happens over and over, each successional stage paving the way for the next, until succession ends with a **climax community**. Climax communities remain unchanged until they are altered by a disturbance, at which point succession begins again.

At this point, you might think of succession as a process that affects only the plants in a community. Wrong! At each stage of succession, different kinds of plants provide habitat for different kinds of animals. Thus, as succession progresses, the variety of animals changes along with the variety of plants.



Eventually the pond is so shallow it becomes a marsh, and wetland plants and animals move in.

Finally the pond fills in completely and becomes solid — but soggy — ground.

MAKE THE **Connection**

Leave it to beavers: A determined beaver can gnaw down a 12-centimeter-wide willow in under three minutes, but on average, the tree-munching rodents drop a tree every other night. They use trees for food, to build dens, and to dam streams. In doing so, beavers change the surrounding ecosystems in profound ways.

Water backs up in front of the dam, creating deep, still pools favored by fish that aren't adapted to the fast-flowing waters of the stream. Dams also cause water to overflow, creating marshy meadows favored by ducks, wading birds, and many wetland animals. New species of plants — such as cattails, rushes, and arrowheads — begin growing in the quiet, shallow water. The plants attract new species of insects, which, in turn, attract new species of insect-eating critters.

Species such as beavers that have a huge effect on the ecosystems in which they live are called **keystone species**. What other plants or animals could be considered keystone species? How would the disappearance of a keystone species affect the biodiversity of a community?

6 PEOPLE and the Environment

BIG IDEAS

- Healthy ecosystems provide goods and services to people and other organisms.
- As human populations grow, their use of ecosystem goods and services increases.
- Science and engineering can be used to monitor and minimize human impacts on the environment.

Healthy ecosystems provide goods and services to people and other organisms.

Think about the things you've used or consumed today. All of them — the food you ate, the clothes you're wearing, the fuel in the bus you rode to school, the pages in this book — they all came from nature. Even things you don't think of as being "natural," such as your cellphone, can be traced to an ecosystem somewhere. Sure, the metals, plastics, and computer chips may have been created in a factory, but the raw materials came from the Earth.

Goods, those products we use or consume, aren't the only things nature provides to us. **Services** are things that are done for you, such as when your dentist cleans your teeth or when your teacher helps you learn long division. Healthy ecosystems also provide services to people and other organisms. For example, water is filtered and made safe to drink as it moves through the water cycle. Oxygen is produced by trees and other plants. Bacteria, fungi, and other decomposers break down waste materials and return nutrients to the soil. By one estimate, the services performed by ecosystems are worth more than $30 trillion a year. But because these services aren't traded on the stock market, they often go unnoticed.

Ecosystem GOODS

Healthy forests provide wood that is used to make all kinds of products, including lumber, furniture, flooring, guitars, baseball bats, charcoal, and paper.

Many medicines are derived from chemicals found in plants and other organisms.

The food we eat, from peaches to peanut butter, can be traced to healthy soils and healthy waters.

The materials used to make clothing — such as cotton, wool, and leather — come from nature.

Nature, What Have You Done For Me Lately?

Here are a few goods and services that healthy ecosystems provide. How many have you used today?

Did you know?

It takes a lot of water to grow the plants we eat. But what about the meat? When you figure in the grain, grass, and water that a cow eats and drinks, each quarter-pound hamburger requires 1,700 liters of water.

RENEWABLE and NONRENEWABLE RESOURCES

Ecosystem goods and services can be divided into renewable and nonrenewable resources. **Renewable resources** are goods and services that are replaced by a healthy ecosystem in a relatively short amount of time. For example, if an oak tree is cut down for lumber, another tree can be planted in its place. **Nonrenewable resources**, on the other hand, take thousands of years to be replaced, and some can never be replaced at all. Coal and oil are examples of nonrenewable resources. It takes many years and very specific conditions to turn dead organisms into fossil fuels. Thus, the coal and oil we burn today to generate electricity and fuel cars will not be replaced in your lifetime, your children's lifetimes, or even your great-great-great-great-great-great grandchildren's lifetimes.

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Point to ponder

Is water a renewable resource? Why or why not?

As human populations grow, their use of ecosystem goods and services increases.

Acre for acre, Missouri's marshes and other wetlands rival any place on the planet in the amount of life they produce. Nearly half of Missouri's 3,200 kinds of plants are associated with wetlands, and more than a third of Missouri's birds depend on wetlands for part of their lifecycle. Shallow wetlands act as nurseries for the offspring of many reptiles, amphibians, and fish. And some of Missouri's most important furbearers — beavers, muskrats, mink, and river otters — depend on wetlands for habitat. When you compare Missouri's wetlands to other ecosystems, only tropical rainforests and coastal salt marshes produce more life per square meter.

Although providing habitat for plants and animals is an important role that wetlands play, the services provided by these soggy ecosystems go even further.

Wetlands curb erosion.

Because they are flat and have lots of vegetation, wetlands slow the flow of runoff. This allows soil and other particles carried by water to settle out before the water reaches nearby streams and rivers. In addition, the roots of wetland plants anchor soil in place so it doesn't wash away.

Wetlands store greenhouse gases.

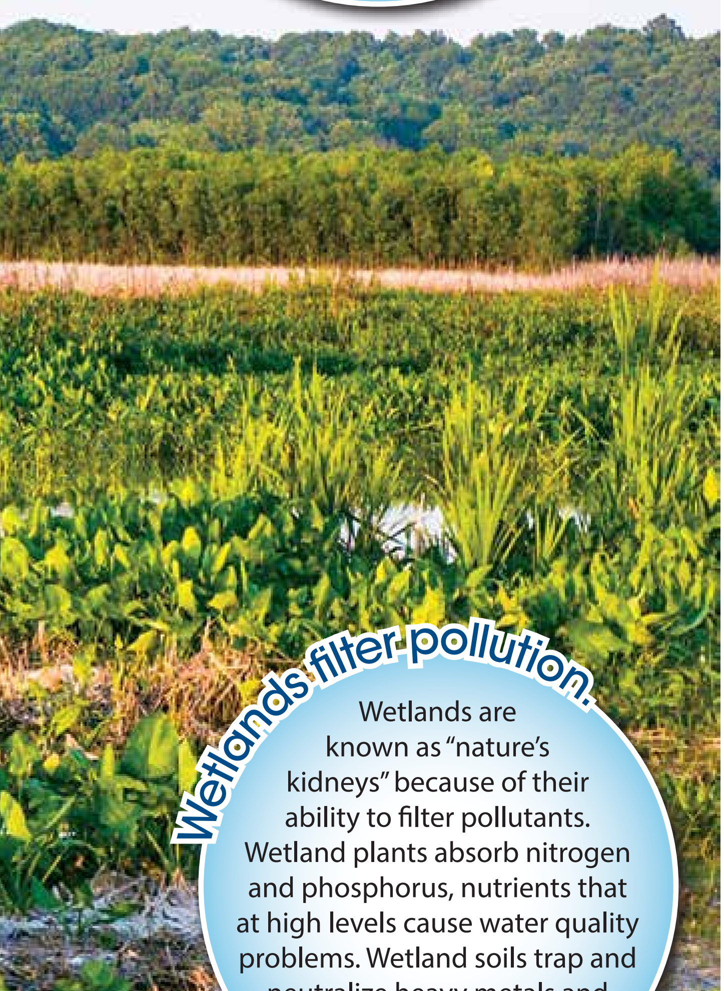
Plants and soils in wetlands store large amounts of carbon. This reduces the amount of carbon dioxide, a **greenhouse gas** that contributes to changes in climate, in the atmosphere.

Wetlands control floods.

Plants and soils in a wetland can absorb up to 18 times their weight in water. This allows wetlands to act like giant sponges, holding water after heavy rains and releasing it s-l-o-w-l-y into watersheds. Because of this, wetlands help to reduce flooding for communities and farmland downstream.

Wetlands offer recreational opportunities.

Many people visit wetlands to birdwatch, fish, hunt, and participate in other outdoor activities. A 1985 study by the U.S. Fish and Wildlife Service found that 107 million people pursued some kind of wetland-related activity, and in doing so, contributed more than $55 billion to the U.S. economy.



Wetlands filter pollution.

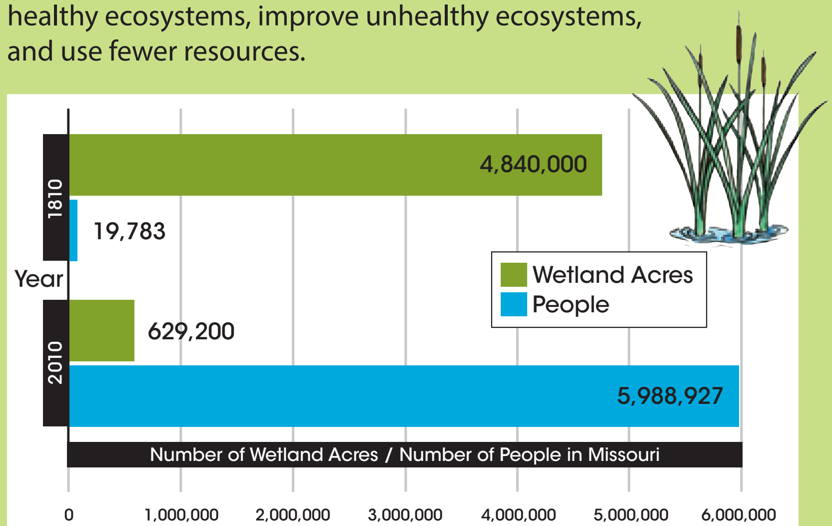
Wetlands are known as "nature's kidneys" because of their ability to filter pollutants. Wetland plants absorb nitrogen and phosphorus, nutrients that at high levels cause water quality problems. Wetland soils trap and neutralize heavy metals and toxins that contribute to water pollution.

Where Did All Our Wetlands Go?

It's only recently that we have come to understand the value of wetlands. In the late 1700s and early 1800s, when Europeans first moved into Missouri, many people viewed wetlands as disease-infested wastelands or as obstacles to progress. Early settlers ditched, drained, and cleared wetlands, deeming wetland soils too fertile to escape the plow and wetland trees too valuable to escape the saw. Other wetlands were drained to make way for rapidly growing cities such as St. Louis, Kansas City, and Jefferson City. In 1800, Missouri had about 4.8 million acres of marshes, swamps, and other soggy areas. Today, less than 15 percent (about 625,000 acres) of those wetlands remain.

The plight of Missouri's wetlands illustrates a simple but significant relationship between human populations and their use of natural resources. Humans, like all organisms, use resources, create wastes, and need places to live. It makes sense, then, that as human populations increase in size, their need for natural resources increases as well. Scientists use the term **ecological footprint** to describe the area of land and water needed to support humans. An ecological footprint can refer to resources needed by one person, an entire country, or the world population. The food you eat, the water you drink, and the electricity you use contributes to your — and the entire human population's — ecological footprint.

To keep pace with Earth's growing human population, human societies must figure out how to make their ecological footprints as small as possible. This will mean harnessing science and technology to find ways to conserve healthy ecosystems, improve unhealthy ecosystems, and use fewer resources.



Science and engineering can be used to monitor and minimize human impacts on the environment.

What happens to the water in your sink when you pull the plug? If you live in Columbia, Missouri, it goes to Eagle Bluffs Conservation Area. In the late 1980s, Columbia's population had outgrown the city's wastewater treatment plant. City planners proposed making the plant bigger and pumping the treated water into the Missouri River. But Columbia's citizens demanded a more natural approach. To satisfy their request, engineers designed a series of shallow wetland pools that use biological processes to clean wastewater. The pools can treat an extra 7 million gallons of wastewater a day, which should keep up with Columbia's growing population. Instead of pumping the treated water into the Missouri River, the engineers designed a way to send it to Eagle Bluffs, a 4,400-acre wetland south of the city. At Eagle Bluffs, the water is used to flood shallow marshes and provide habitat for thousands of ducks, geese, and other wetland creatures. In the 20 years since the project was completed, the engineers have garnered worldwide attention for using ecosystem services to solve a human-made problem.

Turning Wastewater into Wetland Habitat

Once it leaves a sink, bathtub, or toilet, water flows through pipes to Columbia's sewer system.

Water flows downhill through sewer channels to a treatment plant on the outskirts of Columbia. There, it passes through a clarifier, where heavy wastes fall to the bottom of treatment pools.

Once the water is cleaned, it flows into Eagle Bluffs. There it is used to flood shallow marshes that provide habitat for ducks, geese, and other wetland creatures.

From the treatment plant, the partially cleaned water flows into a series of shallow pools overgrown with cattails. The roots of the cattails release oxygen into the water, which microorganisms use to break down wastes and clean the water.

Solutions Through Science (and Engineering)

The engineers who designed Columbia's new water treatment system followed a process that engineers across the world use to solve problems. The process, called **engineering design**, involves several steps.

Define the problem. Before beginning to work on a solution, it's important to clearly understand the problem. Asking questions, making observations, doing research, and gathering data helps engineers fully understand the problem. Once they understand what they're up against, engineers set measurable goals, or criteria. The goals reflect the expected cost, performance, and function of the solution. Goals help the engineers measure whether or not (and how well) the problem has been solved.

Identify constraints. Solutions to a problem are usually limited by time, money, resources, legal concerns, characteristics of the place where the problem occurs, and other constraints. Identifying constraints helps engineers avoid pursuing solutions that won't work because of the constraints. For example, understanding the local climate and weather patterns of an area would rule out certain plants an engineer might consider for use in a school rain garden.

Evaluate different solutions. Once the problem is defined and constraints are identified, engineers brainstorm lots of designs, or solutions. Then they pick the designs they believe will work best and evaluate the strengths and weaknesses of each one to see how well each meets the goals of fixing the problem. Evaluating competing designs, especially when trying to fix an environmental problem, often involves testing how well each one performs under a range of conditions. Models (physical, mathematical, and computer-generated) are useful to test a design without the expense of actually building the design full-scale. Models also help show the design to others and compare competing designs. Data generated from testing models can be used to make decisions about improving the design.

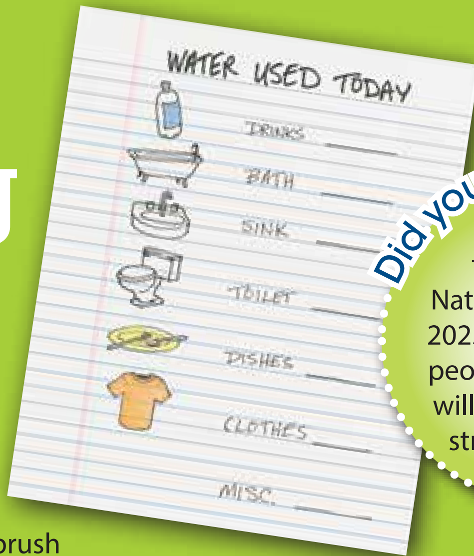
Implement the best design. There is always more than one way to solve any problem. But the goal of an engineer isn't simply to solve a problem. It's to arrive at the best solution. Determining what "best" means requires value judgments from the engineers and the customers they are solving the problem for.

Monitor the design. Once the design is built, an engineer's work doesn't stop. They often continue to monitor and evaluate their design to see if it's performing as expected and to learn if there are ways to improve the design in the future. Engineers use new insights from science to produce advances in their designs. And advances in engineering provide scientists with new ways to observe, measure, and analyze the natural world.

KEEP Discovering

How big is your ecological footprint? To measure a small part of it, keep track of how much water you use in a 24-hour period. Here are a few ways to do so:

- Carry a water bottle that has volume measurements marked on it and use it to record how many liters of water you drink.
- Plug the tub or sink when you take a shower, brush your teeth, or wash your hands, then estimate the volume of water before it goes down the drain.
- Keep track of how many times you flush the toilet. Newer toilets use about 6 liters of water for each flush. Older toilets can use up to 25 liters.
- If you wash dishes or do laundry, be sure to add that water in to your total. Newer washing machines use 50 to 100 liters of water for each load of laundry. The average dishwasher uses 15 to 22 liters of water for each load of dishes.



Did you know?

According to a United Nations report, by 2025 two-thirds of people worldwide will live in "water-stressed" areas.

At the end of the day, add up how many liters of water you used. Was it more or less than you expected? Now multiply your daily water usage by 7.1 billion, which is the estimated world human population. Scientists think that at any point in time, there are about 12,600,000,000,000,000,000 (twelve quintillion, six hundred quadrillion) liters of usable water on the planet. If every person used as much water as you, would there be enough water to go around?

MAKE THE Connection

In the summer of 1993, the Missouri River flooded, cutting a swath of destruction across nine states. The flood washed away bridges, destroyed businesses, drove more than 50,000 people from their homes, and killed nearly 50 people. In Hardin, a small town east of Kansas City, the rushing floodwaters scoured through a hillside cemetery, unearthing dozens of coffins and floating them off into a terrible tangle in the nearby trees. Less severe floods plagued the Midwest in years that followed, and by 2000, the damage from these floods totaled more than $34 billion. As recently as 2015, overflowing waters from the Missouri and Mississippi rivers and their tributaries have flooded towns such as Hermann, St. Charles, and St. Louis and shut down interstates 70 and 44.

If you were an engineer trying to prevent future floods, what would you need to know to define the problem, and what constraints would you need to identify?

Did you know?

The Missouri River is normally no more than half a mile wide. On July 31, 1993, the river stretched 10 miles wide near Kansas City and 20 miles wide near St. Louis.

Glossary

Long-pincered crayfish

Abiotic factor (Page 23) — A nonliving part of an ecosystem, such as water, air, soil, sunlight, or minerals.

Adhesion (Page 4) — The attraction between two molecules of different substances. Compare to **cohesion**.

Aquifer (Page 11) — A layer of rock that is filled with tiny holes through which water moves and collects.

Atom (Page 3) — The basic unit of matter. Atoms are composed of protons, neutrons, and electrons.

Bioblitz (Page 35) — A short, intense effort to record all the living things in a given area.

Biodiversity (Page 31) — A measure of the variety of organisms, genes, and ecosystems found in a given area.

Biological community (Page 30) — The group of populations living in the same place at the same time.

Biotic factor (Page 23) — A living or once-living part of an ecosystem, such as animals, plants, fungi, or other organisms.

Carnivore (Page 19) — An organism that eats animals. Compare to **herbivore** and **omnivore**.

Carrying capacity (Page 28) — The number of individuals in a population that a given area can support at a given time.

Cellular respiration (Page 18) — A chemical process through which organisms change oxygen and sugar into carbon dioxide and water. Energy is released in the process. Compare to photosynthesis.

Climax community (Page 36) — The group of organisms that occur during the last stage of succession and that remain in an area until a disturbance occurs.

Cohesion (Page 4) — The attraction between two molecules of the same substance. Compare to **adhesion**.

Competition (Page 26) — An interaction between two organisms in which both organisms try to use the same limited resource.

Competitive exclusion principle (Page 26) — The idea that when two organisms use the same limited resource at the same time in the same place, one organism will eventually out-compete the other, causing the other to go extinct.

Condensation (Page 11) — The process in which water changes from a gas to a liquid. Clouds, dew, and frost are the result of condensation.

Confluence (Page 13) — The place where two or more rivers or streams meet.

Consumer (Page 19) — An organism that gets energy by eating other organisms.

Crystallization (Page 11) — The process in which water changes from a liquid to a solid. Snow, ice, sleet, and hail are a result of crystallization.

Decomposer (Page 19) — An organism that gets energy by breaking down dead organisms into simple atoms and molecules.

Density (Page 6) — A measurement of the amount of matter in a given volume. To calculate density, divide the object's mass by its volume.

Dew (Page 11) — Water that has condensed onto a surface, such as grass.

Disturbance (Page 36) — A significant change in the environmental conditions of a community.

Early successional community (Page 36) — The first groups of organisms to show up after a disturbance. Also called a **pioneer community**.

Ecological footprint (Page 41) — The area of Earth required to provide ecosystem goods and services used by a person, nation, or population.

Ecosystem diversity (Page 32) — The variety of different ecosystems found in a given area.

Ecosystem goods (Page 38) — The products — such as food, water, and lumber — that ecosystems provide. Compare to **ecosystem services**.

Ecosystem services (Page 38) — The things that ecosystems do for people and other organisms. Compare to **ecosystem goods**.

Electrons (Page 4) — The negatively charged particles that orbit an atom's nucleus.

Engineering design (Page 43) — A logical, step-by-step system used to solve problems.

Erosion (Page 15) — The process by which bits of soil and rock are moved from one place to another by water, ice, or wind.

Evaporation (Page 10) — The process in which water changes from a liquid to a gas.

Exploitation (Page 27) — An interaction between organisms in which one organism benefits by using the other organism, causing the other organism harm. Predators, parasites, and herbivores exploit other organisms to survive.

Food chain (Page 20) — The flow of energy from a producer through a series of consumers as one organism eats another.

Food web (Page 20) — A complicated series of interconnected food chains that shows how energy is transferred among organisms in an ecosystem.


Red-eared slider

Frost (Page 11) — Water that has condensed and then frozen onto a surface.

Gas (Page 6) — A state of matter in which the molecules are spaced far apart and move constantly in random directions. Gases flow and change shape to fill the space they are in, and gases can be easily compressed.

Gene (Page 32) — A section of DNA (the genetic code found in all living things) that affects an organism's outward appearance, behaviors, and abilities.

Generalist (Page 32) — An organism that can use many kinds of resources and survives in many different ecosystems. Compare to **specialist**.

Genetic diversity (Page 32) — The variety of genes found in the individuals of a population.

Gravity (Page 9) — The force that attracts matter to other matter. Objects with a lot of mass have more gravity than objects with less mass.

Greenhouse gas (Page 40) — A gas, such as carbon dioxide or methane, that traps sunlight in the atmosphere as heat.

Habitat fragmentation (Page 34) — When large, continuous blocks of habitat are broken up into small portions as land is cleared to build roads, subdivisions, crop fields, or other human-made developments.

Heat capacity (Page 6) — A measure of the amount of energy needed to raise the temperature of a substance. Substances with a high heat capacity can absorb a lot of energy before their temperature changes.

Herbivore (Page 19) — An organism that eats plants. Compare to **carnivore** and **omnivore**.

Hydrogen bond (Page 4) — A weak bond (attraction) between a hydrogen atom and another atom.

Impermeable surface (Page 11) — A surface such as rock or pavement that does not allow water to soak in or pass through.

Infiltration (Page 11) — Precipitation that soaks into the ground.

Invasive (Page 35) — The trait of an organism to take over a habitat and cause other organisms to decline in number.

Keystone species (Page 37) — A species that has an unusually large effect on the ecosystem in which it lives.

Limiting factors (Page 28) — Things — such as food, water, and shelter — whose scarcity limits how large a population can grow.

Liquid (Page 6) — A state of matter in which the molecules touch each other but can move about. Liquids flow and change shape to fill the space they are in, but they cannot be easily compressed.

Macroinvertebrate (Page 31) — An organism without a backbone that is found in water, and that can typically be seen with the naked eye.

Molecule (Page 3) — The smallest unit of a pure substance that displays all the characteristic properties of that substance. Molecules are formed by two or more atoms.

Mutualism (Page 26) — An interaction between organisms in which both organisms benefit.

Niche (Page 20) — The role or place of an organism in an ecological community.

Nonpoint-source pollution (Page 12) — Pollution that cannot be traced back to a single source but instead comes from many sources. Compare to **point-source pollution**.

Nonrenewable resource (Page 39) — An ecosystem good or service that cannot be replaced or that takes thousands of years to replace. Compare to **renewable resource**.

Nutrient (Page 23) — Any substance required by an organism for growth.

Omnivore (Page 19) — An organism that eats both plants and animals. Compare to **carnivore** and **herbivore**.

Parasite (Page 26) — An organism that feeds off the blood, fluids, or tissues of another organism, usually without killing the other organism.

Photosynthesis (Page 18) — A chemical process through which plants and other producers use energy from the sun to change water and carbon dioxide into sugar and oxygen. Compare to cellular respiration.

Phytoplankton (Page 23) — Microscopic aquatic plant.

Pioneer community (Page 36) — The first groups of organisms to show up after a disturbance. Also called an **early successional community**.

Point-source pollution (Page 12) — Pollution that can be traced back to a single source. Compare to **nonpoint-source pollution**.

Polar molecule (Page 4) — A molecule that is positively charged on one end and negatively charged on the other end.

Precipitation (Page 11) — Water that falls from the sky in the form of rain, sleet, snow, or hail.

Predator (Page 26) — An organism that catches, kills, and eats prey.

Predator-prey cycle (Page 27) — A situation in which a predator influences the population size of its prey and vice versa. This leads to peaks and valleys in the population sizes of both species.

Prey (Page 26) — An animal that is eaten by another animal.

Primary consumer (Page 20) — A consumer that eats primary producers.

Producer (Page 18) — An organism that changes energy from the sun into chemical energy such as sugar.

Protons (Page 4) — The positively charged particles in an atom's nucleus.

Relative abundance (Page 31) — A measurement that shows how abundant one species is compared to all the other species in a given area.

Renewable resource (Page 39) — An ecosystem good or service that can be replaced by a healthy ecosystem in a relatively short time. Compare to **nonrenewable resource**.

Resource (Page 25) — Anything — food, water, shelter, etc. — that an organism needs to grow, survive, and reproduce.

Resource partitioning (Page 27) — A condition in which organisms use a resource in slightly different ways so as to avoid competitive exclusion.

Runoff (Page 11) — Water that flows over the surface of the ground instead of soaking into the ground.

Scavenger (Page 19) — An organism that eats dead plants and animals.

Secondary consumer (Page 20) — A consumer that eats primary consumers.

Solid (Page 6) — A state of matter in which the molecules are stuck tightly together. Solids do not flow or change shape, and they are not easily compressed.

Solute (Page 5) — A substance that is dissolved by a solvent to form a solution. Compare to **solvent**.

Solution (Page 5) — A mixture in which all the substances are equally distributed.

Solvent (Page 5) — A substance that dissolves a solute to form a solution. Compare to **solute**.

Specialist (Page 32) — An organism that requires very specific resources and survives in only a few ecosystems. Compare to **generalist**.

Specialized structure (Page 28) — A feature and/or behavior that helps an organism survive in the environment in which it lives, such as the gills of a fish or the wings of a bird.

Species diversity (Page 31) — A measure of the variety of species and abundance of each species found in a given area.

Species richness (Page 31) — The number of different species found in a given area.

Stomata (Page 10) — Microscopic openings in the leaves of a plant that allow substances, such as water and carbon dioxide, to move in and out of the plant.

Succession (Page 36) — The replacement of one biological community by another over time.

Temperature (Page 6) — A measurement of the average amount of movement of the molecules in a substance. Substances in which the molecules are moving quickly have higher temperatures than substances in which the molecules are moving slowly.

Transpiration (Page 10) — The process in which water is released from within the leaves of a plant.

Tributary (Page 12) — A stream that flows into a larger body of water.

Turbidity (Page 15) — A measurement of how clear or unclear a liquid is.

Warning coloration (Page 28) — Bold colors or stripes that advertise that an organism is dangerous, poisonous, or distasteful.

Water cycle (Page 8) — The movement of water among the Earth's water bodies, atmosphere, land, and living things.

Watershed (Page 12) — An area of land that drains into a body of water.

Weathering (Page 15) — The process by which rock is broken into smaller pieces by water, ice, plants, animals, and changes in temperature.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